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PESTICIDES AND GROUNDWATER IN THE ATLANTIC REGION

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Canada

INLAND WATERS DIRECTORATE
ATLANTIC REGION
WATER PLANNING AND MANAGEMENT BRANCH
DARTMOUTH, NOVA SCOTIA

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Water Planning and Management Branch
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A B S T R A C T

Thirty-nine agricultural pesticides used extensively in the Atlantic Region were reviewed with regard to potential for contamination of groundwater resources. Major agricultural production areas of the Atlantic Region have been assessed in terms of susceptibility to pesticide contamination of aquifers. Priority One pesticides have been so designated because they have been detected in groundwater either in the Atlantic Region, or in other parts of North America. These pesticides, in order of priority, are aldicarb, carbofuran, atrazine, and dinoseb .

Areas within a major agricultural use region, such as Queen's County, Prince Edward Island, should be chosen in order to monitor possible contamination of groundwater. Further information on local hydrogeological conditions and local use patterns for Priority One pesticides is required in order to choose appropriate study sites.

Generally, more data on the environmental fate and behaviour of pesticides in soil and groundwater, long term human health effects, and information on agricultural pesticide use, storage, handling, transportation and disposal should be collected and analyzed as an aid in planning for future groundwater investigations.

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1.0 INTRODUCTION

1.1 Purpose and Scope

It is recognized that serious information deficiencies exist relative to the impact of agricultural pesticides on groundwater in Atlantic Canada. Groundwater is an extremely important resource in the region, particularly in the Maritime Provinces where dependence on groundwater supplies varies from 50% of the population in Nova Scotia to virtually 100% in Prince Edward Island. Much of the prime agricultural land in the region overlies potentially or currently valuable aquifers. In many cases, these aquifers are highly susceptible to contamination, such as in much of Prince Edward Island, the Annapolis Valley of Nova Scotia, and in the Saint John River Valley of New Brunswick.

Pesticide contamination of these aquifers would pose not only a public health and environmental problem, but would also have serious economic implications with respect to water supplies. On the other hand, severe curtailment of pesticide use would have serious economic implications for the agricultural industry. Public concern, already increasing with the continuing revelation of pesticide and other toxic chemcials in groundwater worldwide, has been further heightened by the recent findings of pesticides in groundwater in Prince Edward Island and in the Saint John River Valley in New Brunswick.

It is important that water managers in the region develop a thorough understanding of all aspects of the matter. The current project is designed to contribute to this understanding by (i) developing a list and description of priority pesticides of concern from a groundwater perspective, and (ii) indicating areas in the Atlantic Provinces where groundwater resources are likely to be sensitive to pesticide contamination.

This interim report describes the progress of the first phase of the study, and is put forward for review and comment. There are obvious information gaps, areas needing expansion, and probably, unavoidable inaccuracies in the pesticide use data. Nevertheless, the approach should provide a solid framework on which to build.

1.2 Approach to the Project

Much of the information herein was available in the literature - readily, as in statistics and reports on pesticide use, or more scattered, such as various data on individual pesticides. Considerable effort

(generally with much success) was put into developing contacts of people and agencies involved in the area of interest, locally, nationally, and internationally.

The information presented here is arranged in order of a discussion of priority pesticides, and then by province - agricultural production and major use pesticides, groundwater resources of major agricultural production areas, pesticide contamination incidents, and on-going research.

The Appendix holds the pesticide comparison tables and scoring sheets.

2.0 PESTICIDE REVIEW PROCEDURE

2.1 General

Literature searches were made on the topics of pesticide contamination of groundwater, environmental behaviour and fate characteristics, and human health aspects of the various agricultural pesticides which are widely used in the Atlantic Region. General use patterns and toxicological information were obtained from the "Compendium of Information on Agricultural Pesticides used in the Atlantic Region" which holds information from standard reference sources. Regional use patterns were obtained from Agriculture Canada Registered Pest Control Products Microfiche. Along with literature searching, other jurisdictions were contacted directly for information on their on-going research into pesticides and groundwater. All major use pesticides (Monenco, 1984) were reviewed and placed into three categories.

Priority One pesticides include all those with documented case histories of having caused groundwater contamination through normal agricultural use patterns in North America.

Priority Two pesticides include any of those pesticides included on two important review lists. The first list (referred to in Table A-2 as "federal/ provincial" list) is the list of candidate pesticides for consideration in the Revised Drinking Water Guidelines. Federal departments with input are Environment Canada, Fisheries and Oceans Canada, and Agriculture Canada, with Health and Welfare Canada taking the lead role. Provincial agencies from Nova Scotia, New Brunswick, Newfoundland and Prince Edward Island are also involved. This list has been reviewed by Agriculture Canada, who have deleted some minor use pesticides and have added others which are expected to become major use pesticides in the future. The preliminary list of Candidate Pesticides for Revised Drinking Water Guidelines included a majority of agricultural pesticides as compared with industrial and forestry pesticides.

The second important list, used to identify Priority Two pesticides, is the Draft List of Analytes for the National Survey, compiled by the U.S. Environmental Protection Agency (Cohen, S.Z., 1984b). Both the Office of Drinking Water and Office of Pesticide Programs have reviewed over 600 commonly used pesticides. They have selected sixty pesticides for further investigation with respect to contamination of groundwater, and placed these into three categories

(U.S. E.P.A. - Priority I and II plus the remaining pesticides). Many of these pesticides are major use pesticides in the Atlantic Region of Canada. Additional information has been called for several other pesticides in order to broaden the U.S.E.P.A.

The U.S.E.P.A. review has focussed attention on certain chemical classes - triazines, substituted ureas, substituted acetanilides, carbamates, and some aromatic compounds. The rationale, whether leaching potential or health effects, is not made clear in the memo accompanying the draft list. At any rate, any pesticides which fall into these designated problem classes were placed in our Priority Two Group.

In addition, all major use pesticides, including the remaining ones (Priority Three), were ranked according to leaching potential, human health effects and specific use patterns. Each Priority Group and is arranged in order according to our ranking scores.

2.2 REVIEW CRITERIA FOR RANKING SCHEME

2.2.1 Soil Leaching Potential

Water solubility and soil persistence were the only factors reviewed because these data were most readily available. It is realized that, in order to do a comprehensive analysis of pesticide mobility in soil, and availability to groundwater, one should assess various physical and chemical properties such as vapour pressure, octanol-water partition coefficient, hydrolysis half-life and photolysis half-life. This information was not readily available for each pesticide reviewed so only a rough indication of leaching potential has been obtained.

2.2.2 Human Health Effects

The most important human health factors in regards to groundwater contamination are the possible low dosage, long term effects. Toxicological tests, such as the Ames test, can pinpoint likely mutagenic compounds; while long term animal feeding studies are extrapolated to predict human health effects. Epidemiological studies may also indicate potential adverse health effects from pesticide exposures. Environmental toxicology is a relatively new field and, although progress has been made, one research advocate has termed the science "the Grand Extrapolation" (Henzel, in Lee & Mudd, 1979). As knowledge of possible links of pesticides (and their contaminants or metabolites) with adverse human health effects increase, so do government requirements for toxicological testing

increase. The registration process for a new pest control product may take up to twenty years in Canada, while older registrations are systematically being re-evaluated by Agriculture Canada.

Criteria included in this review include:

Carcinogenicity - cancer promoting or causing

Mutagenicity - causing gene mutations

Teratogenicity - causing birth defects

Oncogenicity - tumor producing

This report is not all-encompassing, so a conservative approach was taken in scoring for human health effects. If there was no information available in the references used, a partial score was given. The fact that research may not have been conducted on carcinogenic potential, for example, does not necessarily mean that there is no problem. Only if all tests were negative for the list of criteria would a score of '0' have been given (A score of '0' did not occur in the review).

The LD_{50} value, or the "median lethal dose" is the minimum quantity of a substance which is fatal to 50% of test population. This is a routine toxicological test of acute or sub-lethal effects and standard test results for rats are available for most pesticides. A comparison of mammalian toxicity can be made between pesticides as follows:

Classification of Mammalian Toxicity

	Oral LD_{50} Rat (mg/kg)	
Insignificantly toxic	5000	low*
Sightly toxic	500 - 5000	
Moderately toxic	50 - 499	moderate*
Highly toxic	5 - 49	high*
Extremely toxic	<5	

*This was further simplified for our purposes.

Often the LD_{50} value for rats is used as an indicator of toxicity to humans, if there is no other toxicological information available. In this review, the pesticide toxicity was assigned a lower rating weight than those factors included under Human Health Effects, because one would not expect such high levels of pesticides in groundwater which would cause acute, or even sub acute effects in humans.

Also accounted for in the rating scheme were problem metabolites, trace contaminants of pesticides, or toxic synergistic effects occurring in combination with another pesticide. Information gaps precluded a separate rating (e.g. for soil leaching potential) of any given contaminant, metabolite, or synergistic effect. When such a case occurred, such as a problem metabolite, the score was assigned to the metabolite itself, and the score was substituted for the score of the parent pesticide. In all cases encountered, this approach worked well because the parent pesticide had a lower score (See Table A-6 in Appendix).

2.2.3 Pesticide Use Patterns

Important considerations in priorizing pesticides and their groundwater contamination potential are the factors of application rate, timing, frequency, and how the pesticide is applied. This information was obtained from the EPS "Compendium of Information on Agricultural Pesticides Used in the Atlantic Region", and from "Pest Control Products Registered in Canada", 1985 Master Edition. This consists of the microfiche copy of each pesticide label registered by Agriculture Canada. As some products have many brand names and formulations, some common agricultural labels were reviewed to obtain the maximum allowable application rate for each pesticide. If, however, a label stated a lower application rate for sandy soils or for the Maritime Provinces, this rate was taken instead. It is recognized that these Agriculture Canada restrictions are designed to minimize off-target contamination problems.

Pesticides applied at a rate of more than one pound per acre (or approximately one kilogram per hectare) should receive a higher degree of consideration than the lower rates (National Agricultural Chemicals Association, 1985). For this review, a figure of 1 kg/ha a.i. (active ingredient) was adopted as the cutoff. Also, pesticides incorporated into the soil or those which are applied directly to the soil may pose a larger threat of groundwater contamination compared with those products applied to row crops or to orchard trees, for example.

Application to orchard crops was given the lowest rating, while soil fumigants, which often do require irrigation to prevent escape of volatile gases, are still rated as the worst cases by virtue of their designed action against soil organisms.

Timing of application in relation to major infiltration events, such as rainfall, also should receive high priority. Often a product label will specify that application should occur in spring or autumn - typically periods of higher rainfall. Other labels may state 'apply under dry conditions only'. These products, of course, received the lowest score for this factor. If no information was found on label checks, a neutral score was assigned.

Finally, because some pesticides may be applied several times per season, in some cases up to 15 times per season, application frequency deserved consideration as well. Products with typical label instructions, such as "repeat as necessary" or "repeat at 7-10 day intervals",were assumed to deserve a higher rating than those labels which imply only one application. In these cases, the product type was considered to be a good indication of the frequency of application. Herbicides and soil fumigants were assumed to be used only once per season, while fungicides and insecticides were assumed to require at least two repeat applications. Ratings were assigned accordingly.

TABLE 1

PESTICIDE RANKING SCHEME

All "Major Use" agricultural pesticides were ranked according to the following criteria:

A) Soil Leaching Potential (max. 20 points)	Points
1. Water Solubility	
> 30 ppm (or 30 mg/l)	10
data not available	
< 30 ppm (or 30 mg/l)	5
	0
2. Soil Persistence	
6 months or half life > 15 days	10
data not available	5
<6 months or half life < 15 days	0

B) Human Health Effects (max. 20 points)		Points
1. Chronic Health Effects (such as mutagenicity, carcinogenicity and teratogenicity)		
documented, lab or human		18
suspected		10
data not available		5
data showing negative some or marginal		2
all tests negative		0
2. Acute Oral LD_{50}, male rat, mg/kg		
0 - 49	high	2
50 - 500	moderate	1
>501	low	0

C) Use Pattern (maximum 16 points)	Points
1. Maximum Application Rate by Active Ingredient (a.i.)	
>1 kg/ha (or >.33 kg/1000 l*)	4
<1 kg/ha (or <.33 kg/1000 l*)	1
2. Application type	
- incorporated into soil	4
- soil fumigant)	
- pre planting)	
- pre emergent)	
- post emergent (assuming immediate)	
- to furrows)	3
- to soil)	
- top killer (assuming tops are)	
plowed under)	
- to field crop)	2
- to foliage)	
- to orchard crops	1
3. Frequency of Application(s) in One Season	
- No information, but if herbicide or nematicide assume only one application per season	1
- Two to three times per season	2
- No information, but if insecticide or fungicide, assume 2 or 3 applications per season	
- Four or more times per season	4
- No information, but label states "repeat as necessary" or "apply at 7-10 day intervals"	
4. Timing of Application in Regards to Infiltration or Runoff Intensity	
- Use Pattern specifies summer use only	1
- Use Pattern specifies under dry conditions only	
No information given in use pattern	2
Use pattern specifies:	
- apply before rain)	
- irrigate after applying)	4
- apply in spring or autumn)	

* Note: In some cases, no rate per hectare is given. The Belmark (fenvalerate) pesticide label equates 150 ml/1000 lto 450 ml/ha. This proportion has been adopted to convert given applied mixture to a rate per hectare, when no other information is available.

3.0 AGRICULTURAL PESTICIDES RANKED AS MOST HAZARDOUS TO THE GROUNDWATER RESOURCES OF THE ATLANTIC REGION

Although a large number of pesticide products are employed in agriculture within the region, generally, the quantities involved are quite small and should be of little consequence to groundwater in and around sites of application. However, several chemicals may present hazardous situations to groundwater because of more extensive or intensive use patterns, the method of application (aerial/ground spraying), environmental fate (soil and pesticide characteristics affecting pesticide movement into groundwater, leaching, adsorption, absorption), and toxicity to humans. Figure I illustrates the complexities of the various processes and interactions involved in determining the behaviour and fate of pesticides in the soil.

Major use agricultural pesticides for the Atlantic Region were designated by Monenco (1984) in two different manners, according to how much information was available for their survey. For New Brunswick, information on quantities of active ingredient (versus product) was available, so a pesticide was designated a "major use" if sales exceeded 500 kg (and/or 1) active ingredients (a.i.) for insecticides, or 1000 kg (and/or 1) for herbicides and fungicides.

For the provinces of Nova Scotia, Newfoundland and Prince Edward Island, a pesticide was designated "major use" if sales were more than 1000 kg (and/or 1), on the assumption that average concentration of active ingredient is about 50%.

The pesticides aldicarb, carbofuran, atrazine, and dinoseb are "major use" pesticides which have been detected in groundwater, either in the Atlantic Region, or somewhere else in North America. These have been designated as Priority One pesticides in relation to hazard to groundwater. They have been ranked, along with the remaining 36 pesticides reviewed. The following sections outline the basic properties of Priority One Agricultural pesticides as ranked during this study. Table 2 lists Priority One Agricultural Pesticides for the Atlantic Region.

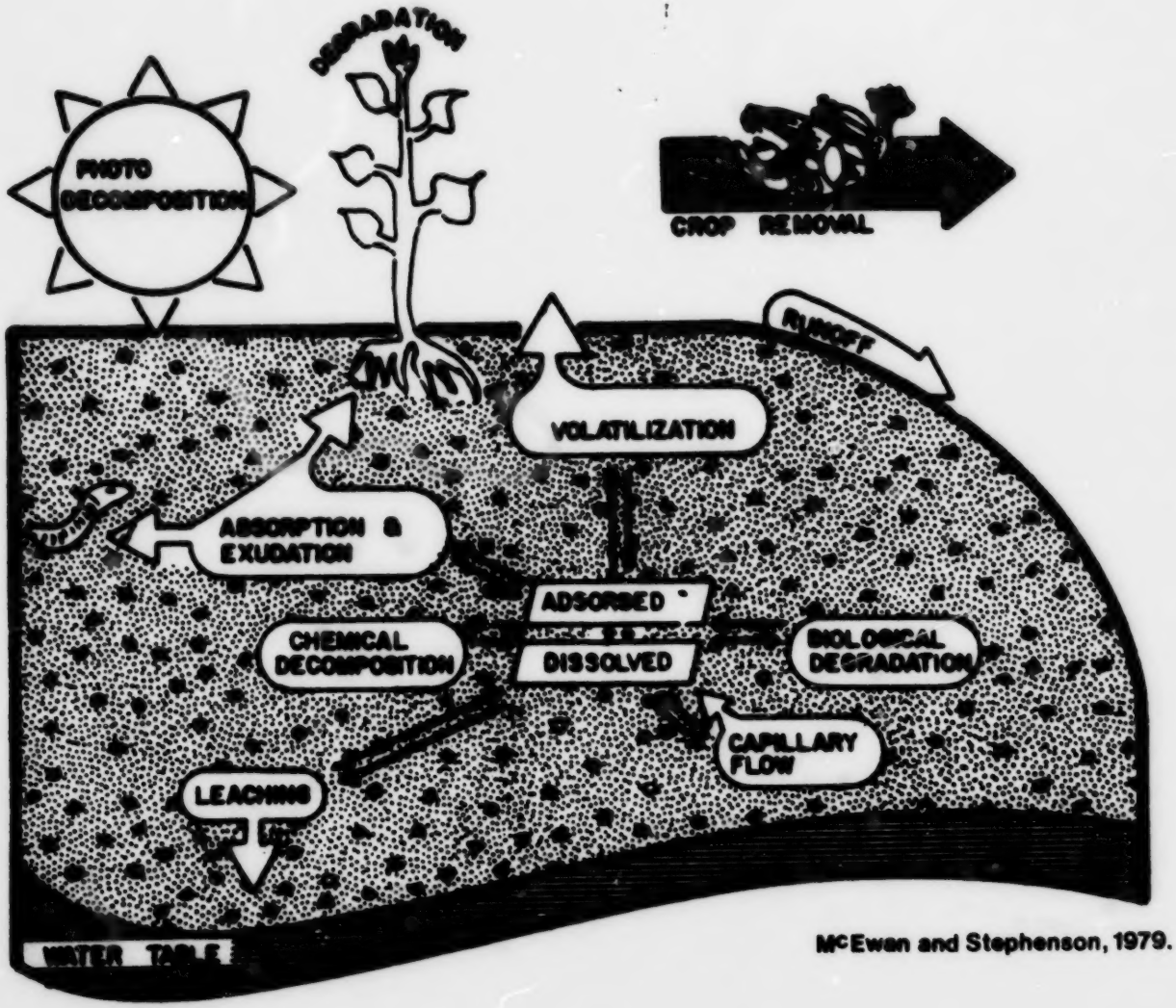

Figure 1. Processes Influencing the Behaviour and Fate of Pesticides in the Soil Environment

TABLE 2

PRIORITY ONE AGRICULTURAL PESTICIDES FOR THE ATLANTIC REGION

Priority One - Detected in Groundwater (Canada or U.S.A.)

Common Name	Score	Type	Action	Where Detected	Major Use Atl. Prov.	Fed/Prov. List (1) (requestor)	EPA List of Analytes (2)
aldicarb	(45)	CBM	I, M, A	NB, PEI	NB, PEI NS, DOE	NB, PEI	I
carbofuran	(43)	CBM	I, A, N	NY, WI (USA)	NS, NB, PEI Nfld.	--	I
atrazine	(36)	triazine	H	IA, NB, WI (USA)	NS, NB, PEI	--	I
dinoseb	(32)	dinitrophenol	I, H	NY, PEI	NB, NS	--	I

Key to Pesticide Actions: I - insecticide, H - herbicide; F - fungicide; N - nematicide; A - acaricide; GR - growth regulator.

Key to Pesticide Types:
- CBM - carbamate
- EBD-CBM - ethylene bis dithiocarbamate
- OP - organophosphate
- OC - organochlorine
- Subst. urea - substituted urea
- SP - synthetic pyrethroid

References

1. Federal/Provincial Working Group, 1985: List of Candidate Chemicals for Revised Drinking Water Guidelines.

2. Cohen, S.Z., 1984b, United States Environmental Protection Agency, Memo to Chairman of ODW/OPP Work Group regarding Criteria for Chemical Selection and Attached List of "Draft Analytes for the National Survey".

Information on the basic properties of the pesticides is primarily from the following references which are included at the end of the report:

Agriculture Canada, 1982

EPS, 1984

Guenzi, W.D., 1974

Landreville, G., 1985

Lewis, G., 1985

Monenco Limited, 1984

Parisienne, R., 1985

Seatech Investigative Services, 1982

Sittig, M., 1980a and 1980b

Thomson, W.T., 1973 and 1974

Weed Science Society of America, 1974

Worthing, C., 1983

3.1 **ALDICARB** ($C_7H_{14}N_2O_2S$)

TRADE NAMES: Temik; Carbanolate; Abush; UC21149; U.S.D.A. EWT-27 093; WHO OMS0771; A13-17093.

TYPE OF COMPOUND: Aldicarb is a methylcarbamate oxime insecticide, acaricide, and nematicide. Its chemical name is 2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl) oxime.

USE: Aldicarb is a major use agricultural insecticide for both New Brunswick and Prince Edward Island, where it is used exclusively on potatoes. It is also a minor-use insecticide in Annapolis Valley, Nova Scotia (Monenco, 1984).

PROPERTIES: A white, crystalline solid with a slightly sulphurous odour, Aldicarb forms colourless crystals; melting point - 99 to 101°C; volatility is 0.05mm Hg at 25°C; solubility at room temperature: 6 g/L water. It is stable except to concentrated alkali. It is a cholinesterase inhibitor.

Aldicarb degrades rapidly in soil, and is converted to aldicarb sulfoxide, a major product after 12 weeks (Coppedge et al, 1967). It is eventually hydrolized to sulfone and nontoxic products nitrite sulfoxide, oxime sulfoxide and to the oxime. Five additional products were unidentified. The sulphur atom of the molecule is readily oxidized to form the sulphoxide which is more slowly oxidized to the sulfone (aldo-xycarb).

About 10% of the original aldicarb is converted to aldicarb sulfone (Pimental, D., 1981). The sulfoxide has solubility |330g/L water. Conversion of aldicarb to its sulfoxide plus sulfones was attributed to microbial oxidation. Aldicarb is also lost from soil by volatilization (Bull, 1968). The metabolic fate of aldicarb is different than that of other carbamate insecticides because it possesses an extra hydrolyzable bond.

Hough and Thomason (1975) reported that active concentrations of aldicarb sulfoxide persisted longer in a silt loam than in a clay soil.

Moisture is required to release the active chemical from the soil, and aldicarb can be leached through wet soil easily shortly after application.

No adverse effects have been observed with respect to compatibility with other pesticides, but one should avoid exposing aldicarb to lime or other alkaline products which quickly decompose the carbamate.

PERSISTENCE Altering the pH of several different soils before addition of aldicarb had little effect on degradation rates. However, under conditions of low moisture, the type of soil was a controlling factor. In construction sand, the half-life for all toxic aldicarb materials was only one day, but in sandy loam soils, 50% degradation was complete only after four to seven days. Equal treatment of clay loam soil mixtures containing 5, 20 or 50 ppm of aldicarb yielded respective half-lives for the total toxic complex of one week, three weeks and five weeks. A half-life of 32 days has been found for aldicarb under field conditions. In the aquatic environment, the half-life is reduced to 5 to 10 days depending on physical and chemical properties of the water body.

TOXICITY Extremely toxic to mammals. Acute oral LD_{50} in rats is 0.93 mg/kg. The chemical is very reactive to moisture, meaning that it can quite easily be ingested, inhaled or absorbed through the skin. Aldicarb is a potent inhibitor of acetylcholinesterase, preventing brain messages from completing their planned circuit.

COMMENTS: Since aldicarb is: (i) very reactive to moisture; (ii) observed to degrade/hydrolyze rapidly in soil into toxic metabolites; (iii) has synergistic compatability with other pesticides; (iv) has been found in groundwater samples in seven out of thirteen states in concentrations ranging from 5-50 ppb (Cohen, S.Z. et al, 1984b), and in groundwaters in New Brunswick and Prince Edward Island; (v) use has been

banned in several states; (vi) is the most toxic chemical registered with the U.S.E.P.A.; (vii) is considered a major-use agricultural pesticide employed in the Atlantic Provinces, primarily New Brunswick and Prince Edward Island; and (viii) is classified as a toxic chemical by EPS, this insecticide warrants further consideration to be identified as a priority pesticide hazardous to groundwater in the Atlantic Region.

Aldicarb is banned in areas of the U.S. where soils are permeable, acidic, and relatively cold, where rainfall is plentiful such as Suffolk County, Long Island, Maine, Wisconsin, Connecticut, Delaware, Massachusetts, Maryland, New Jersey, Rhode Island and Virginia. Such conditions are also prevalent in much of the intensive agricultural areas of Atlantic Canada.

3.2 CARBOFURAN ($C_{12}H_{15}NO_3$)

TRADE NAMES: Furadan, Nia 10242, Bay 70143, ENT 27164, EMC 10242, D1221, Curator, Yaltox.

TYPE OF COMPOUND: Carbofuran is a broad spectrum, systemic and contact heterocyclic methylcarbamate insecticide, nematicide and acaricide. Its chemical name is 2,3-Dihydro-2, 2-dimethyl-7-benzofuranyl methylcarbamate.

USE: Carbofuran is a major-use agricultural insecticide in all four Atlantic Provinces. It is primarily used on potatoes in New Brunswick; corn, potatoes and vegetables in Nova Scotia; mostly potatoes and some use in vegetable and strawberry production in Prince Edward Island; and corn in Newfoundland. It is a major substitute for the more persistent pesticides such as DDT, Aldrin, Chlordane and Heptachlor. It should not be used with certain herbicides such as propanil.

PROPERTIES: A white, crystalline solid; melting point - 150 - 152°C; stable under neutral or acid conditions, unstable in alkaline media; water solubility 700 ppm at 25°C; vapour pressure: 2×10^{-5} mm Hg at 33°C; slight phenol odour. Density is 1.180 g/ml at 20/25°C.

Studies indicate that significant residues may accumulate in aquatic and soil systems from operational use. The pesticide appears to be particularly long-lived under conditions of low pH, which may be relevant to Atlantic Region environmental conditions (EPS, 1981).

The major primary metabolites of carbofuran are 3-hydroxy carbofuran, a small amount of 3-keto carbofuran, and a conjugated metabolites derived from hydrolytic products such as 3-keto phenol and carbofuran phenol. 3-hydroxy-N-hydroxymethyl carbofuran is a major biotransformation product of N-(2-toluenesulfenyl) carbofuran. Ring hydroxylation can also take place with nonaromatic rings. The position of hydroxylation for carbofuran is at the 3-position (Matsumara, 1975)

PERSISTENCE: In soil, half-life is 30 - 60 days.

TOXICITY: Acute oral LD_{50} in rats is 8-14 mg/kg which rates as highly toxic. It acts as a cholinesterase inhibitor through ingestion and inhalation.

COMMENTS: As carbofuran is: (i) soluble; both it and its hydrolysis products have been demonstrated to be highly toxic; (ii) has synergistic pesticide combination interactions resulting in marked responses by plants and insects compared with singly applied compounds; (iii) has been

detected in groundwater samples in the United States in concentrations ranging from 1 - 50 ppb (Anon., 1983); (iv) considered a major-use agricultural pesticide in all four Atlantic Provinces; and (v) is classified as a toxic chemical by EPS (1981), this insecticide has potential to be hazardous to groundwater in the Atlantic Region.

Information gaps and potential problem areas which exist with respect to this pesticide are:

(a) residue monitoring to determine carbofuran levels in aquatic and soil systems has not been conducted;

(b) The ultimate fate of the parent compound and its metabolites in various environmental components is poorly understood;

(c) The teratogenetic and carcinogenic effects of carbofuran and its metabolites have not been adequately documented.

3.3 **ATRAZINE** ($C_3H_{14}ClN_5$)

TRADE NAMES: Aatrex, Fenamin, Inaker, Primaze, Radozin, Semparol, Zezin, Vectal, Aatram, Atratol, Gesaprim, Primatol.

TYPE OF COMPOUND: Atrazine is a polar basic ionic triazine herbicide. Its chemical name is 2-chloro-4-ethylamino-6- isopropylamino-s-triazine.

USE: Atrazine is a major-use agricultural herbicide for New Brunswick - grain; Prince Edward Island - corn; and Nova Scotia - corn, strawberries, blueberries, weeds.

PROPERTIES: Atrazine is a colourless powder with a melting point of 175 - 175°C. Vapour pressure is 40 uPa at 20°.C (3 x 10 mm Hg at 20°C) or 1.4 x 10^{-6} mm Hg at 30°. Solubility at 20°C is 30 mg/L water (33 ppm at 25°C). Moisture activates the chemical, and atrazine forms salts with acids.

Slow hydrolysis to the herbicidally inactive 6-hydroxy analogue (alternative) occurs at 70°C under neutral conditions, and is more rapid in acid or alkali conditions. Atrazine is compatible with other pesticides when used at normal rates. Metabolites are dealkylated. It is readily metabolised to hydroxyatrazine and amino acid conjugates. Hydroxyatrazine can be further degraded by dealkylation of side chains and by hydrolysis of resulting amino groups on the ring.

The diffusion coefficient for atrazine was found to increase as the soil water increased in a silty clay loam (Scott and Phillips, 1972). Diffusion of atrazine (and also simazine) increased with an increase in total surface area and organic matter content [contrary to other reports stating decreased diffusion under these conditions (Lavy, 1970)]. Volatilization of atrazine from soil occurs with increases in temperature (Kearney et al., 1964).

PERSISTENCE: Residual effects usually disappear within the same growing season. Dry or cold conditions prolong persistence. Atrazine residues may persist in receiving streams throughout the year. Applied at a high rate, atrazine is a soil sterilant, killing all plant life present. Atrazine may move laterally with water; it also leaches downward. Downward and lateral movement found in soil. Persists for 7 to 12 months. Dissipates by hydrolysis and microbial photo decomposition. More readily adsorbed on clay or muck soils than on soils of low organic content.

TOXICITY: Acute oral LD_{50} for rats is about 3000 mg/kg, hence this product is only slightly toxic. Inhalation hazard is low in humans. No apparent skin irritation or other toxic manifestations in humans. One farmer in Prince Edward Island experienced tingling fingers after handling atrazine.

On the basis of chronic studies, an ADI (Allowable Daily Intake, Man) for atrazine was calculated at 0.0215 mg/kg/day.

COMMENTS: Since atrazine is: (i) a soil sterilant killing all plant life present when applied at a high rate; (ii) is activated by moisture; (iii) observed to move downward and laterally in soil; (iv) undergoes hydrolysis in soil and water; (v) has synergistic compatibility with other pesticides (e.g. carbofuran) leading to increased phytotoxicity; (vi) has been found in groundwater samples in the States in positive level concentrations ranging from 0.3 - 3.0 ppb (Cohen, S.Z. et al, 1984a); (vii) is considered a major-use agricultural pesticide employed in the Atlantic Provinces; and (viii) is classified as a toxic chemical (EPS, 1981), this herbicide warrants further consideration to be identified as a priority pesticide hazardous to groundwater in the Atlantic Region.

Atrazine is one of the most common herbicides used on corn in the Atlantic Region, is environmentally persistent and bioaccumulation may occur (EPS, 1981).

3.4 **DINOSEB** ($(C_{10}H_{12}O_5N_2)$)

TRADE NAMES: Premerge; Dinitro Weed Killer; Sinox; Chemox; Gebutox; 2-sec.-butyl-4,6-dinitrophenol; 2,4-dinitro-6-sec.-butyphenol; dinitro-burylphenol; DNBP; DNOSBP; DNSBP; Dow Top Killer; Dytop, Elgetol.

TYPE OF COMPOUND: Dinoseb is an acidic, ionic, organic, dinitrophenol herbicide compound. Its chemical name is 2-(1-methyl- n-propyl)-4, 6-dinitrophenol (alkanolamine salts)

USE: Dinoseb is a major use agricultural pesticide employed extensively throughout the Atlantic Provinces as a potato top-killer in New Brunswick as a herbicide on vegetable crops (beans, peas); an apple growth regulator (blossom thinner) in Nova Scotia; used in field peas in Prince Edward Island; and in Newfoundland is used for weed control in potatoes.

PROPERTIES: Water solubility is 2.2×10^2 umoles/l or 50 ppm, pure, and melting point is at $42^{\circ}C$. The commercial product is a dark reddish brown liquid. Vapour pressure is $.171 \times 10^{-4}$ at 30°. Being a phenol, the compound forms salts with inorganic and organic bases, some of which are readily soluble in water, i.e. ammonium salt - a crystalline solid decomposing on heating to ammonia + parent phenol.

Dinoseb has a high mobility in soil systems (Harris, 1969). Weber (1972) reported that adsorption of several weakly acidic herbicides by acid muck (pH4) was in the order -dinoseb | picloram |2,4-D = dicamba. Water solubilities of these pesticides are 45, 430, 650 and 4500 ppm, respectively, indicating an inverse relationship. Similarly, dinoseb is a weaker acid than the other herbicides, suggesting that relatively fewer molecules were in the anionic form at the pH of the soil.

PERSISTENCE: Average persistence is 2 - 4 weeks at normal rates of application (Seatech, 1982). It may leach in sandy soils.

TOXICITY: Acute oral LD_{50} for rats = 50 mg/kg. Dinoseb is readily absorbed through skin. Dusts irritating; inhalation may cause serious illness. Mild to moderate eye irritation. The dinitro compounds DNP, DNOC and dinoseb are uncouplers of oxidative phosphorylation and may be acutely toxic.

COMMENTS: (i) Aquatic environments may be threatened by dinoseb through drift or runoff, especially in sandy soils where the tendency to leach is greater; (ii) a case of stream contamination in the region has been documented; (iii) the long term effect of dinoseb on non-target

ecosystems is not well known; (iv) although dinoseb is used extensively in the Atlantic Region, there has been little residue monitoring; (v) since dinoseb is readily soluble in water, it has the ability to be mobile in soil systems; (vi) is toxic; (vii) a major-use agricultural pesticide employed in the Atlantic Provinces (New Brunswick and Nova Scotia); (viii) has been detected in the United States in groundwater samples in positive level concentrations ranging from 20 - 60 ppb. (Cohen, S.F. et al, 1984). This herbicide warrants further consideration to be identified as a key priority pesticide, potentially hazardous to groundwater in the Atlantic Region.

4.0 NEW BRUNSWICK

4.1 Agricultural Production in New Brunswick and Major Use Pesticides

Approximately 50% of all agricultural activity in New Brunswick occurs in Madawaska, Victoria and York Counties (New Brunswick Department of Agriculture and Rural Development, 1983). The tree fruit industry includes about 361 hectares and small fruit farming includes about 122 hectares, mostly strawberries. Two thousand three hundred fifteen hectares are in vegetable production, predominantly beans and green peas. Of the 6,377 hectares in field crops, most are tame hay, potatoes and oats.

Figure 2 illustrates the major crop producing and population distribution areas of New Brunswick. In many cases, major crop areas could only be identified by county through Agricultural statistics information (Monenco, 1984). Agricultural areas along the Saint John River, especially in Carleton County, are the ultimate destinations of the majority of agricultural pesticides in New Brunswick.

A list of the "major use" agricultural and horticultural pesticides for New Brunswick is tabulated in Table 3. An insecticide was considered major use if the total 1982 retail sales exceeded 500 kg (and/or litres) active ingredient (a.i.). Herbicide and fungicide compounds were designated as major use in the 1982 sales records reported sales exceeding 1000 kg (and/or litres) active ingredient. From Table 3, it can be seen that more agricultural pesticides are used on potato crops in New Brunswick than any other crop. It is not possible to accurately derive the total amount of pesticides used on a particular crop (such as potatoes) because most products may be used on other crops as well.

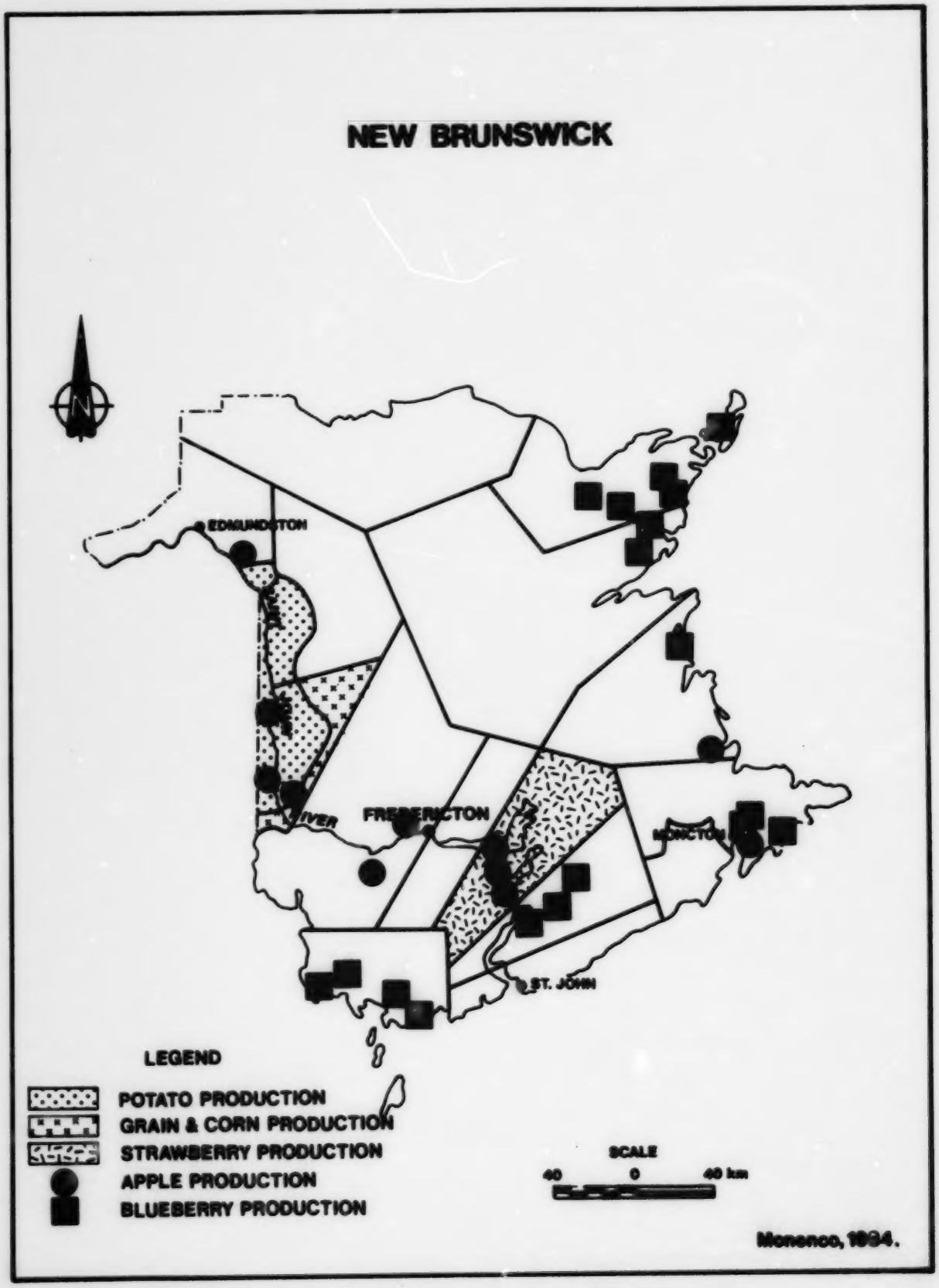

Figure 2. Major Agricultural Areas of New Brunswick

TABLE 3

MAJOR USE AGRICULTURAL PESTICIDES IN NEW BRUNSWICK

AS DETERMINED BY 1982 RETAIL SALES VOLUMES (MONENCO, 1984)

Common Name	Quantity of Product Sold (total kg or l)	Quantity of Active Ingredient Sold (Total kg or l)	Probable Use
Insecticides			
aldicarb*	17,461.5	1,746.1	Potatoes
azinphos-methyl	1,616.7	729.6	Orchards
carbaryl	1,496.9	823.3	Potatoes
carbofuran*	9,000.2	2,942.5	Potatoes
disulfotan	12,435.4	1,865.3	Potatoes
malathion	1,476.4	723.4	Orchards, grains, strawberries
mineral oil	3,335.0	3,230.1	Orchards
phorate	60,348.5	9,052.2	Potatoes
pirimicarb	3,302.0	1,651.0	Potatoes, orchards
trichlorfon	3,965.0	2,570.9	Variety crops
Herbicides			
alachlor**	3,748.5	1,741.7	Potatoes
atrazine*	3,324.0	1,915.8	Grain
2,4-D	8,017.0	4,287.5	Corn, grain, pastures
dalapon	10,035.1	7,425.9	Potatoes
dinoseb*	104,532.8	35,543.5	Potatoes
diquat	60,709.0	12,141.8	Potatoes
EPTC	2,542.5	2,034.2	Preplanting
linuron	2,119.1	1,021.9	Potatoes
MCPA	10,396.0	5,130.7	Grain, corn
metribuzin	9,054.3	3,061.8	Potatoes
paraquat	5,326.5	1,065.3	Potatoes
Fungicides			
captafol	2,675.0	1,284.0	Potatoes
captan	7,715.5	4,178.1	Apples
chlorothalonil	12,672.0	5,119.0	Potatoes
dichloran	2,088.0	1,566.0	Potatoes
mancozeb	252,619.0	171,287.5	Potatoes, apples
metiram	16,630.0	3,758.9	Apples
thiabendazole	7,662.0	3,447.9	Potatoes
thiophanate methyl	6,494.0	4,545.8	Potatoes, orchards, strawberries
zineb	6,760.0	5,408.0	Orchards
Growth Regulators			
Maleic Hydrazide	18,815.0	6,264.0	Potatoes

* Priority One

** No longer "major use". Registration has been temporarily cancelled. (personal communication, N. McNair, Agriculture Canada, 1986)

4.2 Groundwater Resources in Agricultural Regions

4.2.1 Central Area - Edmundston Planning Area

This area includes the drainage basin of that stretch of the Saint John River between the City of Edmundston and a point just upstream from the confluence of the Tobique River.

Bedrock Aquifers

The area is underlain by highly folded sedimentary rocks of the Ordovician, Silurian and Devonian System, which has intrusions of a few Devonian stocks, sills or dykes. Micaceous and partly micaceous sandstone occur from Rivière Verte towards the northwestern part of the area. Around Ste. Anne de Madawaska and Grand Falls, lie silty argillite and argillaceous sandstone. In the St. Léonard area, the predominant bedrock geology consists of green slate, sandstone argillaceous limestone, and shaley limestone. Water yields from bedrock depend upon fracture permeability and average yield is about .45 l/sec. from wells that 30 metres in depth on average (N.B. Department of the Environment, 1981). Water quality is generally good, but with iron and manganese problems around St. Léonard. Groundwater tends to be hard to very hard in the Rivière Verte area. In the farming district around Grand Falls, nitrate concentrations have been found to exceed acceptable limits from time to time.

Surficial Aquifers

Surficial deposits are important as aquifers in this region - most deposits are located along the Saint John River and its tributaries. By way of infiltration galleries, these aquifers can give up to 50 l/sec of good quality water. McCain Foods Ltd. obtains its water from three wells drilled 20 metres into the gravel aquifer of the Saint John River. Well yields from confined and unconfined aquifers may be as high as 230 l/sec (MLM, 1981). All municipalities (except St. Basile which is coming on stream) use the extensive surficial deposits along the Saint John River as water supplies (New Brunswick Department of the Environment, 1981).

Susceptibility of Aquifers to Contamination

Because of the high permeability of soil cover, or the lack of soil cover, overlying the glacio fluvial deposits along the Saint John River, and the generally low lying topography of such formations, these aquifers are very prone to contamination from both surface water pollution (by induced infiltration), and land use activities. This is true

especially in the area around Grand Falls, St. André and Drummond, where most agricultural production is concentrated.

4.2.2 Southern Area - Edmundston Planning Region

This area is comprised of the New Brunswick portion of the Aroostook River Basin.

Bedrock Aquifers

Bedrock geology consists of folded Ordovician argillites and argillacious sandstone. Secondary permeability, fracture flow, is responsible for the usual water yeilds which are of 0.4 l/sec. at a depth of 30 metres (N.B. Department of the Environment, 1981).

Surficial Aquifers

Surficial deposits along the Saint John River have yields that exceed 10 l/sec. Usual depths of these deposits are about 30 metres. Elsewhere, till cover is usually less than 1 metre in thickness. Groundwater usage, both industrial and domestic, is minimal because of the small population base. Water quality is expected to be good except for moderate to high water hardness and elevated nitrate values (N.B. Department of the Environment, 1981).

Susceptibility of Aquifers to Contamination

This area is within the potato belt, where pesticide use is quite intensive. Surficial deposits along the Saint John River and its tributaries are prone to contamination of groundwater because the generally loamy, sandy soils would offer little protection from surface infiltration.

4.2.3 Tobique Area - Fredericton Planning Region

The Tobique area, which contains the Tobique River, is located in the northern portion of the principal agricultural production area.

Bedrock Aquifers

Much of the southern basin is underlain by highly folded sedimentary rock sequences, while areas in the north are dominantly intrusive and extrusive igneous and flat lying sedimentary rocks. Well yields from this area are generally low, but are enough for domestic supplies (0.3 to 0.8 l/s) (N.B. Department of the Environment, 1980).

Surficial Aquifers

Unconsolidated deposits that are important aquifers are found in the Tobique River Valley. Water supplies developed in these deposits may have yields in excess of 7 l/s (N.B. Department of the Environment, 1980). Water quality depends primarily on the rock type. The southern part of the basin is expected to have hard water. Groundwater use in the Tobique River Basin is limited to domestic supplies from drilled and dug wells.

Susceptibility of Aquifers to Contamination

Agricultural land amounts to about 7% of the total area. Soils vary generally from gravely sand loams to clay loams over the main bedrock aquifer region around the Tobique River. Surficial deposits are located in low lying areas and are typically overlain by gravelly sandy loams which offer very little no protection from infiltrating surface contaminants.

4.2.4 The Woodstock to Tobique Area - Fredericton Planning Region

The Woodstock to Tobique area is the drainage basin of that reach of the Saint John River between the junction of the Tobique River with the Saint John River and the Town of Woodstock. Covering most of Carleton County, this area is known as the Potato Belt of New Brunswick.

Bedrock Aquifers

The area is predominantly underlain by highly folded calcareous and argellaceous sedimentary rocks and slates, sandstones and conglomerates of Silurian and/or Ordivician age. In the southeastern part of the Woodstock to Tobique area, there occurs a small area of flat lying Mississippian and Pennsylvanian sandstones and siltstones, and conglomerates with minor intrusive igneous rocks.

In these bedrock formations, groundwater is confined to fractures within the rock. The average depth of wells in the area is approximately 26 metres with an average yield of 0.9 l/s (N.B. Department of Environment). Wells as deep as 275 metres are also known to exist, and they yield very little water. Sufficient water is usually found for domestic water systems, but yields from bedrock aquifers are not large enough to support major municipal or industrial water supplies.

Natural water quality from the bedrock in this area can be described as good. There are minor amounts of iron and manganese occurring in this groundwater. The water is generally found to be hard to very hard because of the calcium associated with the bedrock. High

nitrates levels have been detected in the groundwater of farming districts. This is probably because of intensive fertilizer usage.

Surficial Aquifers

Overburden deposits are generally less than 1 metre in depth. Glacialfluvial deposits along the Saint John River and its major tributaries are locally important for their reserve of groundwater. Water yeilds are in excess of 7.6 l/sec (MLM, 1981).

These outwash channel and terrace deposits are the most important aquifers (New Brunswick Department of the Environment, 1980). The Towns of Woodstock, Hartland and Aroostook use groundwater from these deposits and the aquifers partially supply McCain Foods of Florenceville. Emergency water supplies for the Villages of Perth-Andover and Bath are also obtained from the glaciofluvial deposits. The water quality from these unconsolidated glacial deposits is very good.

Susceptibility of Aquifers to Contamination

The Woodstock to Tobique Area has an agricultural land use of approximately 28% of the county, which is the highest in the province. Soil cover offers little protection to the important river outwash deposits which lie topographically low. With the intensive use of agricultural pesticides in this area, the Woodstock to Tobique area should be considered as vulnerable to contamination of groundwater.

4.2.5 Queens County - Saint John Planning Region

Bedrock Aquifers

Most of the county is underlain by the Pennsylvanian-Triassic formation, which exhibits water yields of .15 - .38 l/sec per 60 m of saturated section. Permeability is due to fracturing, not lithology, hence the low yields. This water supply is suitable for domestic purposes. Information is lacking on water yields from the other bedrock hydrostratigraphic units which occur in the south eastern end of the County. These include the Devonian granites, Silurian-Devonian and the Mississippian formation.

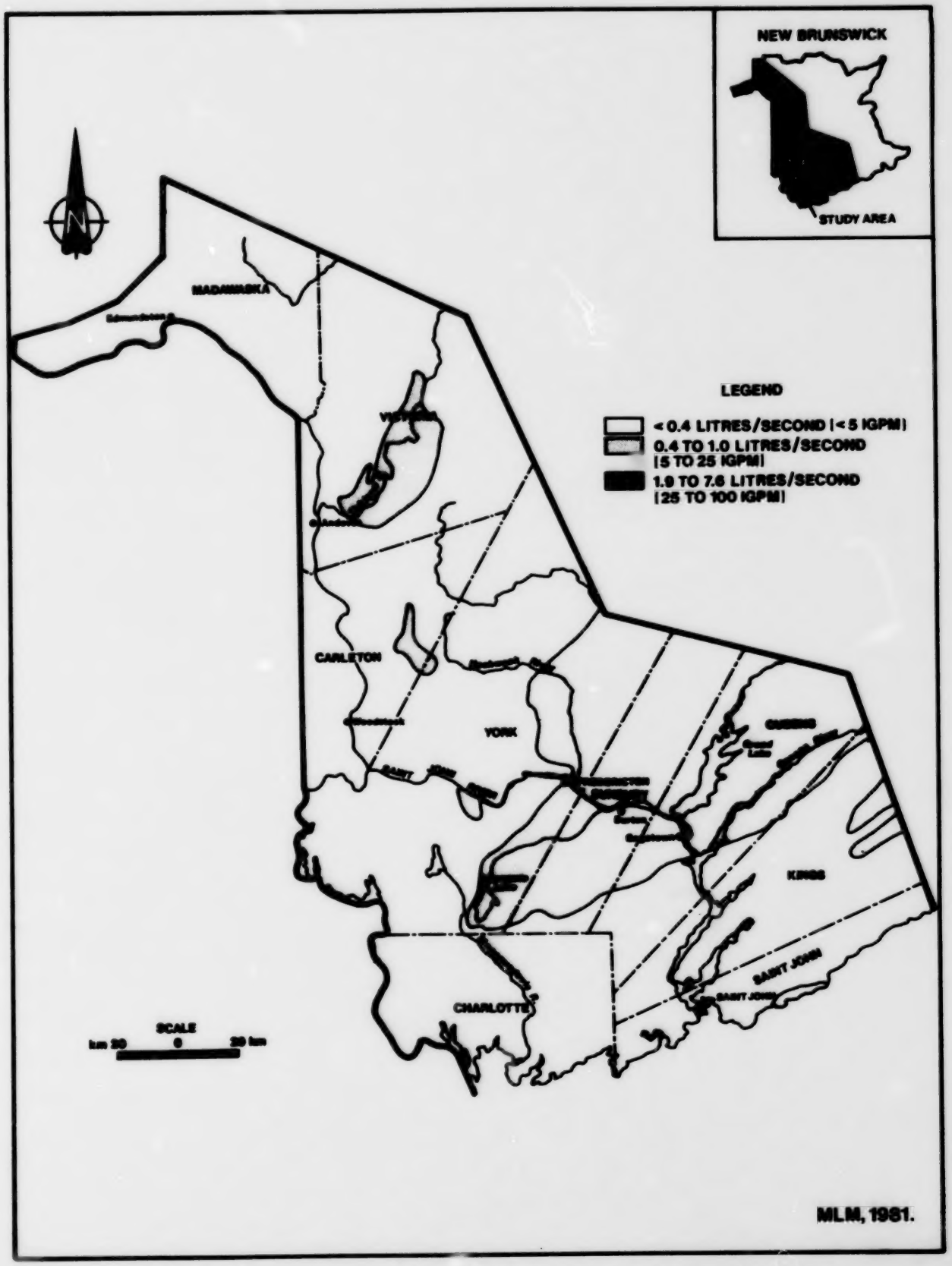

Figure 3. Bedrock Aquifers in New Brunswick Agricultural Areas

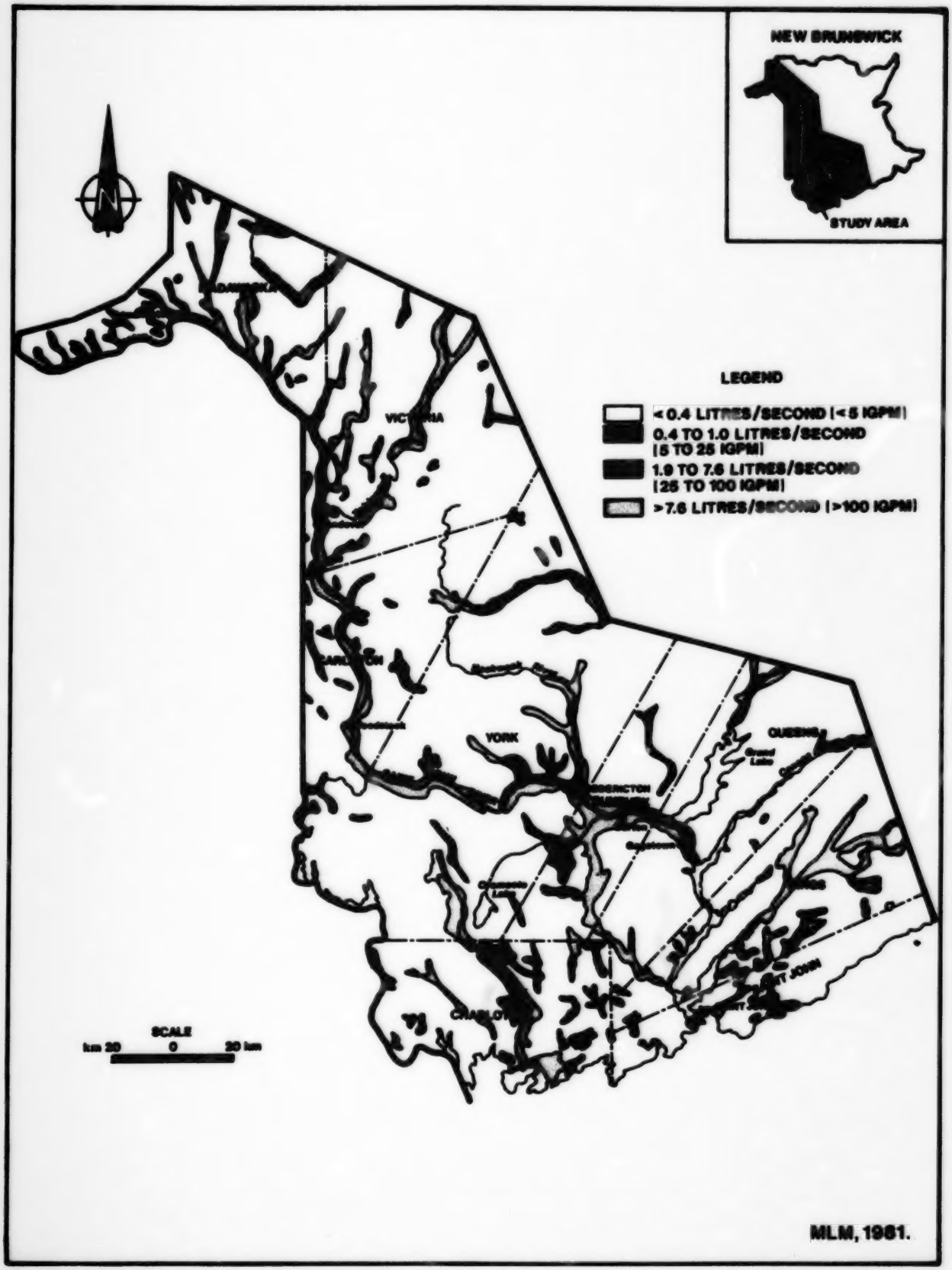

Figure 4. Surficial Aquifers in New Brunswick Agricultural Areas

Surficial Aquifers

Surficial deposits are not mapped for the entire county, however, glacial meltwater deposits along the Nerepis Valley provide sufficient yields for domestic usage. One industry also utilizes waters from this aquifer.

Susceptibility of Aquifers to Contamination

The aquifers in this area do not appear to be overly susceptible to contamination of groundwater. Tills derived from the parent material in this region are of a fine texture, and farming activity is not as intensive as in the Potato Belt.

4.3 Contamination Incidents and On-going Research

The discovery of aldicarb and nitrates in groundwater (Ecobichon et al, 1985) at several sites in New Brunswick has emphasized the need to describe and control the conditions under which contamination of aquifers has occurred. In the farming district of the northwestern half of the region, excessive nitrate concentrations have been found in private water supplies. If high levels of nitrate are due to excessive fertilizer being applied to farmland, this may indicate pesticide contamination as well (Cohen, 1984a). Improper well construction increases the incidence of such contamination in wells. Carleton County in New Brunswick is the major crop production area, and likely receives the greatest amount of pesticides.

A study was carried out by the New Brunswick Department of Health (Ecobichon, D.J. et al, 1985) concerning the use of agricultural chemicals in the Saint John River Basin. The study was conducted after tests on 100 wells in nearby Houlton, Maine, showed signs of aldicarb in 57 wells of between 1 and 10 ppb; and 10 samples had levels between 11 and 30 ppb (The Observer: Vol 73, No. 5, 2 February, 1983, p.7, Hartland, New Brunswick). The area selected for study was in Carleton County on the west side of the Saint John River between Woodstock and Florenceville. 14). Attention was focussed on two pesticides used extensively in the potato production areas of New Brunswick - aldicarb and the ETU metabolite of mancozeb.

Aldicarb residues were detected in groundwater at one sample site in a region in which homes were adjacent to potato fields. Aldicarb is a systemic insecticide documented as appearing and persisting in several agricultural regions of Canada and the U.S. The results of the aldicarb

testing in Carleton County were as follows: in the range of readings 1 to 29 ppb; 20 of the readings were under 10 ppb; four were between 10 and 14 ppb. ETU was not detected in any of the samples.

This survey of well water quality has yielded useful information on the extent and serious nature of groundwater contamination in the agriculturalized regions of New Brunswick.

A baseline study of the transboundary aquifers in the Saint John River Valley was made in 1984 by the Water Planning and Management Branch, Inland Waters Directorate. One aim of the study is to provide baseline data for the delineation of the interactions between surface waters and groundwater. Polluted surface waters can impact upon groundwater quality and vice versa. The study area generally encompasses the New Brunswick potato belt, and the study includes pollution sources such as agricultural activities, solid waste disposal, storage and disposal of petroleum products, and highway deicing programs. Along with high nitrate levels, trace levels of aldicarb have been detected in well water samples collected in this area.

<u>New Brunswick Department of the Environment Well Monitoring Program</u>

Beginning in 1982, New Brunswick Department of the Environment has been sampling 50 wells which lie adjacent to fields treated with aldicarb (Temik). Of 105 analyses performed, there have been 22 positive readings:

2 samples | 10 ppb aldicarb

4 samples in range of 5.0 - 9.0 ppb aldicarb

16 samples with levels less than 5.0 ppb.

Detection limits have varied from 1 ppb to .5 ppb as methodology improves. Two individual wells stood out with 9 positive readings and 2 levels | 10 ppb aldicarb between them (personal communication, W. Sexsmith, 1986).

An additional 65 analyses were done on well water samples from the potato belt (Carleton and Victoria Counties). All tests showed negative results for azinphos-methyl, disulfotan, phorate, and the ethylene bis dithiocarbamate metabolite - ETU (personal communication, W. Sexsmith, 1986).

5.0 NOVA SCOTIA

5.1 Agricultural Production and Major Use Pesticides

The major agricultural production in Nova Scotia occurs in the Annapolis Valley. About 40% of the land area of Annapolis and Kings Counties is occupied farms and nearly 38% of the farm land is improved. Nearly 70% of the improved land is in crops (Monenco, 1984).

Approximately 90% of agricultural production in Annapolis and Kings Counties comes from the Annapolis-Cornwallis and Gaspereaux Valleys. The important tree fruit industry includes about 4,666 ha in orchard - 4330 ha in apples; 219 in pears; 74 in plums and prunes; 42 in peaches. Small fruit farming includes about 171 acres, mostly strawberries, raspberries and cranberries. About 2,434 ha are in vegetable production, predominantly beans, green peas, carrots and cabbage. Of 36,319 ha in field crops, most are hay, oats, corn, wheat and potatoes (Nova Scotia Department of Agriculture and Marketing, 1983). Other crop production areas are Hants and Cumberland Counties.

5.2 Groundwater Resources in Agricultural Regions

5.2.1 Eastern Annapolis Valley

Bedrock Aquifers

The Valley is underlain mainly by sandstone, conglomerate and arkose of the Wolfville Formation, which conducts water mainly by means of primary permeability. This is sometimes limited by calcitic cementing. Flowing artesian conditions exist in some areas. With yields ranging from 0.19 - 21.0 l/sec, this sandstone is one of the better aquifers in Nova Scotia. Average well depth is 67 metres in the Wolfville Formation. In the Annapolis Valley, wells are routinely drilled through surficial deposits into the Wolfville Formation. Water quality is generally good.

Groundwater usage is expected to increase in the future as surface watercourses are becoming inadequate for increasing municipal and industrial demands. For example, the towns of Kentville and Wolfville presently supplement their municipal water supplies with groundwater (personal communication, J.E. Gibb, 1986). Recently the Town of New Minas has experienced contamination of its groundwater supply by the toxic chemical perchloroethylene. Presently, groundwater is also used extensively in the food processing industry.

TABLE 4

MAJOR USE AGRICULTURAL PESTICIDES IN NOVA SCOTIA

AS DETERMINED BY 1982 RETAIL SALES VOLUMES (MONENCO, 1984)

Common Name	Quantity of Product Sold (Total kg and/or l)	Probable Use
Fungicides		
benomyl	1,932.0	Fruit
captan	21,826.0	Orchards, apples
chlorothalonil	1,140.0	Field crops
dichlone	4,948.0	Fruit Trees
mancozeb	35,763.0	Orchards, potatoes, tomatoes
zineb	4,329.3	Fruit, tobacco, vegetables
Herbicides		
alachlor**	4,353.0	Corn, potatoes
atrazine*	3,385.1	Corn, blueberries, weeds
chloroxuron	2,218.0	Strawberries, vegetables
2,4-D	1,756.0	Grain, strawberries
dinoseb*	14,311.6	Beans, peas, apple growth regulator
glyphosate	2,968.5	Fruit, cereals, non-crop weeds
hexazinone	3,942.7	Blueberries
MCPA	3,146.1	Grain
paraquat	2,279.6	Fruit, berries, vegetables, field crops
Insecticides		
azinphos-methyl	1,241.0	Orchards, blueberries, strawberries
carbaryl	5,384.2	Potatoes, vegetables
carbofuran*	7,592.0	Corn, potatoes, vegetables cereal
disulfoton	2,159.5	Cereals, fruits, vegetables
malathion	1,956.9	Fruit, vegetables, root crop, grain
mineral Oil	1,909.2	Orchards
phorate	2,116.0	Corn, vegetables

* Priority One

** No longer a major use pesticide (Registration has been temporarily cancelled (personal communication, N. McNair, Agriculture Canada, 1986)

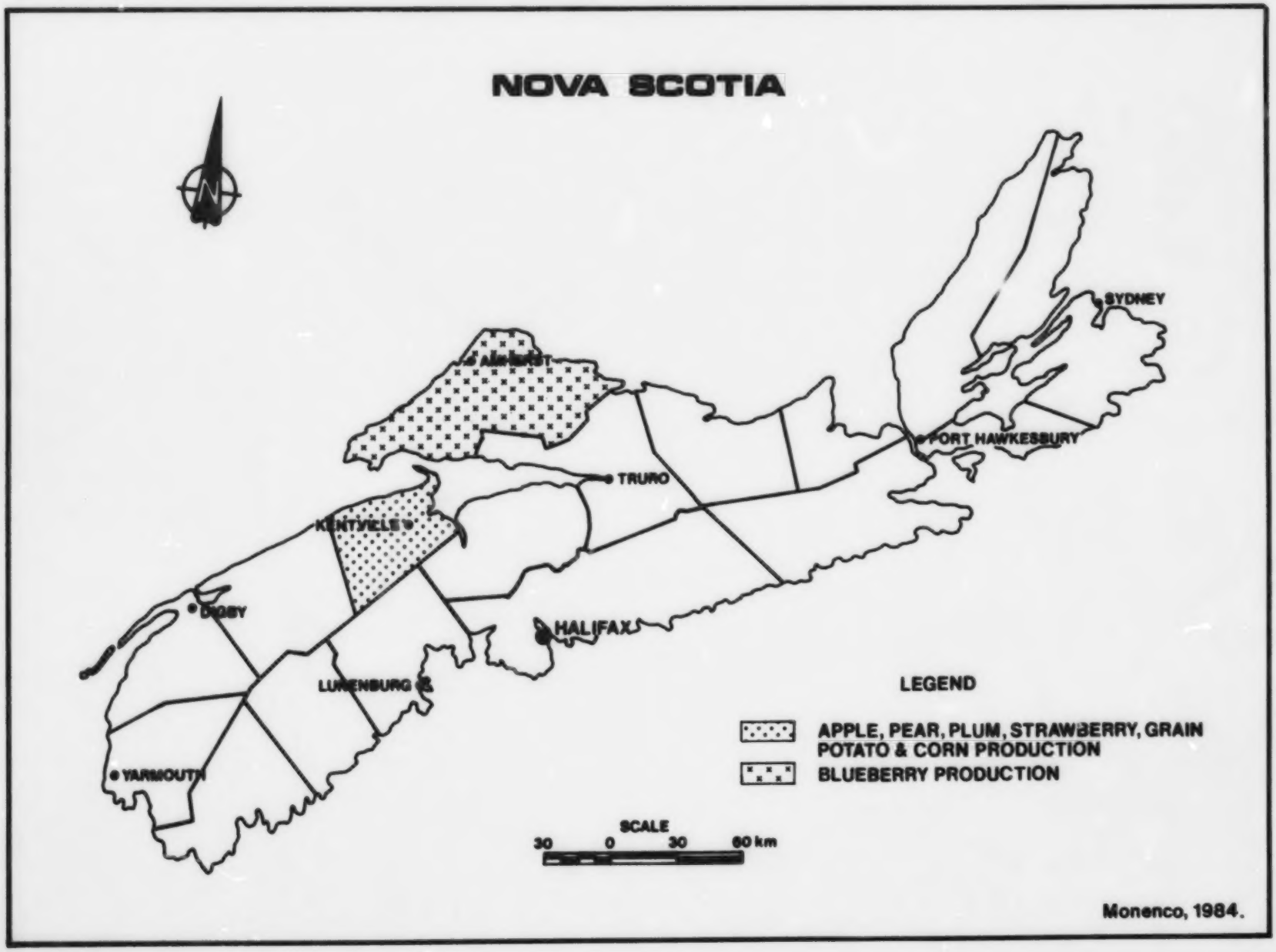

Figure 5. Major Agricultural Areas of Nova Scotia

Surficial Aquifers

Surficial deposits often have higher yields than the sandstone of the Annapolis Valley. The most important deposits lie in the eastern part of the Valley where extensive outwash deposits are spread throughout the low-lying areas of the Valley (Trescott, 1968). There are excellent examples of outwash deposits in the Coldbrook, Greenwood, Berwick and Tremont areas. Yields in these outwash sand and gravel aquifers are generally more than 7.6 l/sec. Various kame fields in the Valley have yielded from 1.9 - 7.6 l/sec of good quality water (MLM, 1981).

Stream alluvium deposits are found along the Annapolis River and its tributaries and can yield sufficient water for domestic purposes. Till is quite sandy over the Wolfville Formation, so there is the possibility for domestic wells anywhere in the till.

Susceptibility of Aquifers to Groundwater Contamination

Soils in the Annapolis Valley are generally sandy; 60% of Kings County soils are derived from moderately coarse textured parent material. Most agricultural production occurs from these soils (Cann et al, 1965). Pesticide use in these sandy soils is expected to be intensive. Local conditions vary and some areas may be well protected by a thick soil cover. Generally, however, groundwater in the Annapolis Valley is susceptible to contamination from activities on the land surface.

5.2.2 Western Annapolis County

Bedrock Aquifers

Most of the agricultural areas of the Western Annapolis Valley are underlain by the Wolfville Formation, which is a good aquifer, and the Blomidon Formation, which provides enough water for domestic needs, although quality is often poor. The sandstone and conglomerate of the Wolfville formation exhibits intergranular porosity because of only partial cementing. Permeability in the claystones, siltstones and silty sandstones is mainly by way of thin stringers of sandstone and fractures. Pump test data indicate that long term water yeild is 7.2 l/sec/30 m of saturated section within the Wolfville Formation, both in this area and the rest of the Annapolis Valley (see Section 5.2.1 of this report).

Water is primarily derived from the Blomidon Formation through sandstone stringers and lenses, and secondarily from joints in siltstones

and claystones. Average well yeild is less than 3.0 l/sec/30 m of saturated section.

North Mountain basalt yields water through contacts between lava flows, as much of its original fracture permeability has been lost because of secondary mineralization. Yields of 0.1 - 1.5 l/sec/30m of saturated section occur from this formation.

Granite, slate and quartzite underlie a majority of the remaining area of the Western Annapolis Valley. Permeability in granite is due primarily to joints, except near the surface where weathering has occurred. Well yields are usually .1 l/sec/30 m in granite. In slate and quartzite, an average yield of .1 l/sec/30 m of saturated section may be expected (Trescott, 1969).

Surficial Aquifers

Glaciofluvial deposits store the most water per unit volume in the Western Annapolis Valley. Permeability may range up to 100 times that of the Wolfville Formation aquifers. Ice contact-stratified drift deposits at Lequille, Clementsvale and Seaview may be able to suppport one or two wells each producing 7.6 l/sec/30 m of saturated section (Trescott, 1969).

Smaller kames and eskers and stratified sand and gravel lenses scattered throughout the area yield lesser amounts of water than the larger deposits mentioned.

Other fluvial deposits in the area are normally fine grained, except for around Moose River. Permeability in the heavier-textured tills is limited to joints and thin sandy lenses and stringers. Most domestic wells are constructed in till, but these often dry up as the water table recedes during dry summers (Trescott, 1969).

Groundwater quality is good to excellent for most uses, except in slate areas where iron and manganese levels are high.

The Town of Digby will soon begin looking for a groundwater source to supplement its surface water supply (personal communication, J. Gibb, 1986). In the area from Karsdale to Granville Ferry, wells could be developed that would yield 3.8 - 23 l/sec (Trescott, 1969).

Susceptibility to Contamination

As in the remainder of the Annapolis Valley, surficial deposits are highly vulnerable to infiltration of contaminants from land use activities, although agricultural production is not as intensive as in

the Kings County section of the Valley. Bedrock aquifers are susceptible to contamination, depending on thickness and texture of overburden, which are variable in this area.

5.2.3 Windsor-Hantsport-Walton Area, Hants County

Bedrock Aquifers

Much of this area is underlain by the Windsor group, with fracture and solution permeability dominating. In the shales, yields are very low, while in the carbonates (limestones and dolomites) water yields are very high. Overall, yields are expected to range from 1.9 - 7.6 l/sec (M.L.M., 1981). Water quality is limited by hardness and high sulphates.

The Scotch Village Group and Horton Groups make up most of the remaining bedrock area with Wolfville sandstones and conglomerates around Cambridge. The sandstone components of the Horton group are good aquifers with yields up to .8 - 7.6 l/sec (or 1.9 - 3.8 l/sec per 30 m of saturated section).

Minor occurrences of slates, quartzites and granites (Halifax and Goldenville Formations), possess limited fracture permeability, however zones of weathered rock exhibit much higher permeability. The town of Hantsport supplements its surface water supply with groundwater, and the MacKenzie Creamery in Windsor, as well as the greenhouses in Falmouth use groundwater.

Surficial Aquifers

Glaciofluvial deposits in the Windsor-Hantsport-Walton area are very productive aquifers. Large deposits of sand and gravel in bedrock valleys occur at St. Croix and Windsor Forks. Yields should be more than 7.6 l/sec here (Trescott, 1969), while sand and gravel deposits occurring near Falmouth may extend to the kame field along French Mill Brook (Trescott, 1969). Other surficial deposits in this area are of finer grained material and thus are poor aquifers.

Susceptibility of Aquifers to Contamination

Agricultural land use is not as intensive as in the Annapolis Valley; only about 10% of the land area is improved (Trescott, 1969). Soils are generally derived from sands and gravel or sandy til, so little protection is offered to the underlying aquifers. Overall, the susceptibility of groundwater to contamination from land based activities in the Windsor- Hantsport-Walton area is less than in the Annapolis Valley.

5.2.4 Cumberland County

Bedrock Aquifers

The county is generally underlain by sandstone, siltstone, shale, conglomerate and coal of the Cumberland and Pictou- Stellarton Groups. Although yields of |53 l/sec have been encountered (Monenco, 1969), well log reports indicate that water yields generally range around 0.4 l/sec for the bedrock aquifers in Cumberland County (M.L.M., 1981). High variability of yields in these formations is likely because of secondary permeability from fractures, faults or joints.

The Town of Amherst utilizes groundwater as its municipal supply, and the remaining county areas rely on groundwater for domestic supplies (CBCL, 1984).

Surficial Aquifers

Glaciofluvial deposits are found along the major rivers - River Philip, Wallace River, Diligent River and Parrsboro River. Water yields from these stratified sand and gravel aquifers range from 1.9 l/sec to more than 7.6 l/sec (M.L.M., 1981).

Susceptibility of Aquifers to Contamination

These deposits are generally overlain by loam, sand and sandy loam soils, so there is little protection from contaminated surface runoff.

5.2.5 Truro Area, Colchester County

Bedrock Aquifers

In the east central area of Colchester County in the Debert to Truro area, lie deposits of red sandstone and conglomerate which yield from 19 - 1.1 l/sec/30 m of saturated thickness. Permeability is primarily through primary porosity in the Wolfville Formation (Hennigar, 1972).

Other formations in the study area include the Horton Riversdale and Canso Groups which all exhibit yields up to 1.5 l/sec through fracture permeability, with variability yields from the Cumberland and/or Pictou Groups, consisting of conglomerate, sandstone, and shale, and may reach 1.9 l/sec, owing to flow along joints and bedding planes (Hennigar, 1972).

The igneous, metamorphic and sedimentary rocks of the Cobequid Complex yield up to .76 l/sec because of fracture permeability, while

similar yields are obtained from the limestone, shale, gypsum, and anhydrite of the Windsor Group.

The largest production wells are drilled into the Wolfville Formation, with yields ranging from 15.8 - 47.4 l/sec. These wells are located at Bible Hill (Nova Scotia Agricultural College), Debert, and the Town of Truro.

Surficial Aquifers

Outwash sand and gravel deposits, mostly around the Truro Area, exhibit excellent yields of over 76.0 l/sec where recharge is available through hydrologic connection with a surface source.

Yields from the quite wide spread ice contact stratified drift deposits may be as high as 38.0 l/sec, dependent on thickness and source of recharge. Glacial tills generally yield only small amounts of water, but enough for a domestic supply (Hennigar, 1972)..

Except for areas around the North and Salmon Rivers where salt water intrusion is a problem, water quality from surficial deposits is very good to excellent. Some tills exhibit the same water quality problems as water extracted from the parent bedrock.

Only a few small domestic water supplies are obtained from the uncolsolidated sand and gravel deposits by way of well points or open casings. There is potential for further development of these surficial groundwater sources, however.

Susceptibilty of Aquifers to Contamination

Colchester County was not designated as a major agricultural production area by Monenco 1984, however, there is agricultural activity, mainly dairy farming. Approximately 6.8 percent of the county is improved farmland, with 4.5 percent as cropland, and 2 percent as improved pasture (Hennigar, 1972).

Approximately half of the Truro Study Area is overlain by tills derived from coarse textured parent materials, so these areas are susceptible to infiltration of contaminants from farming activities.

5.3 Contamination Incidents and On-going Research

Very little work has been carried out in Nova Scotia with respect to monitoring pesticides in groundwater. Four isolated cases of wells believed to be contaminated with pesticides have been documented (Cameron A., 1985). The results of the water quality analyses performed on these

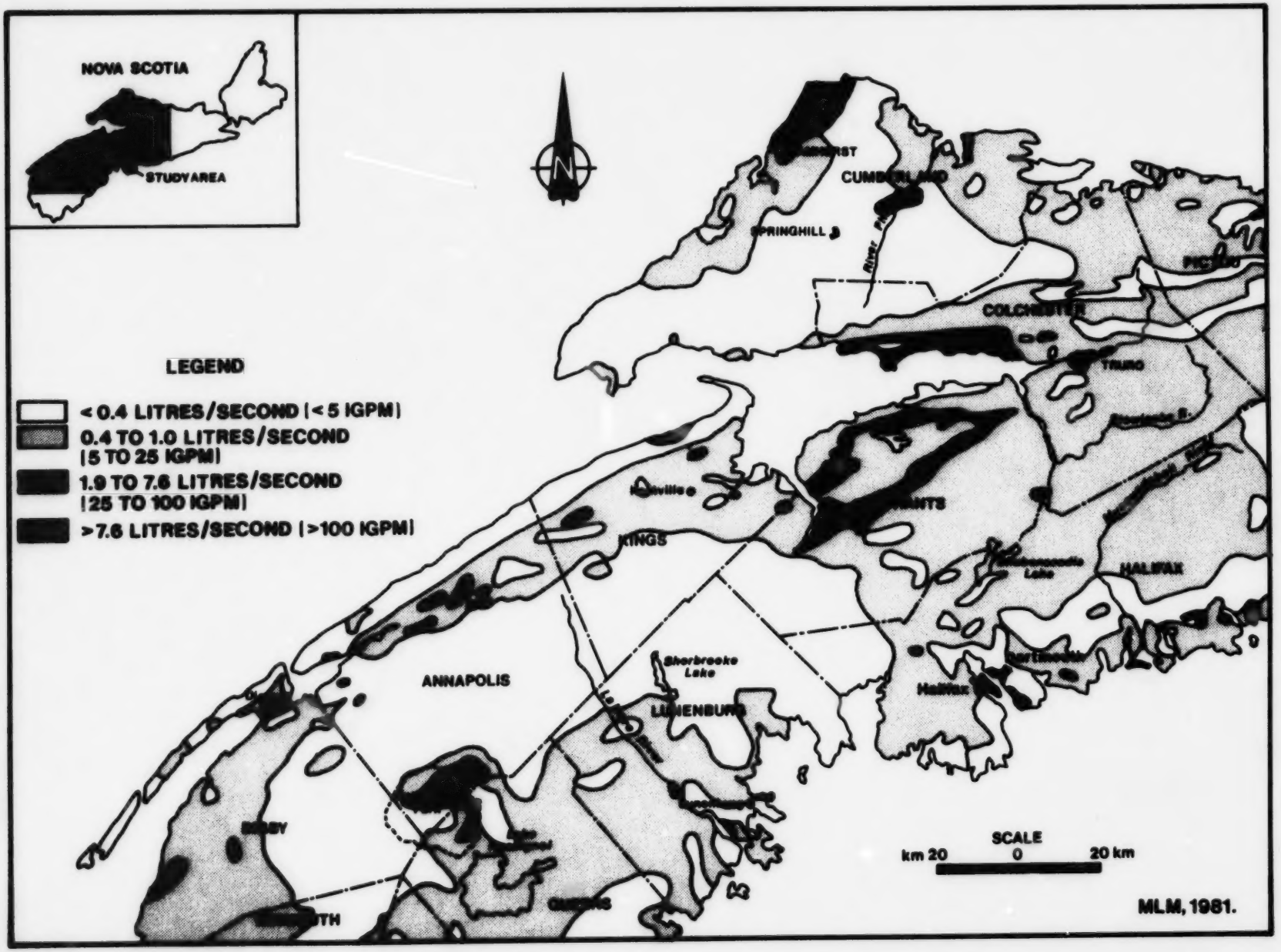

Figure 6. Bedrock Aquifers in Agricultural Areas of Nova Scotia

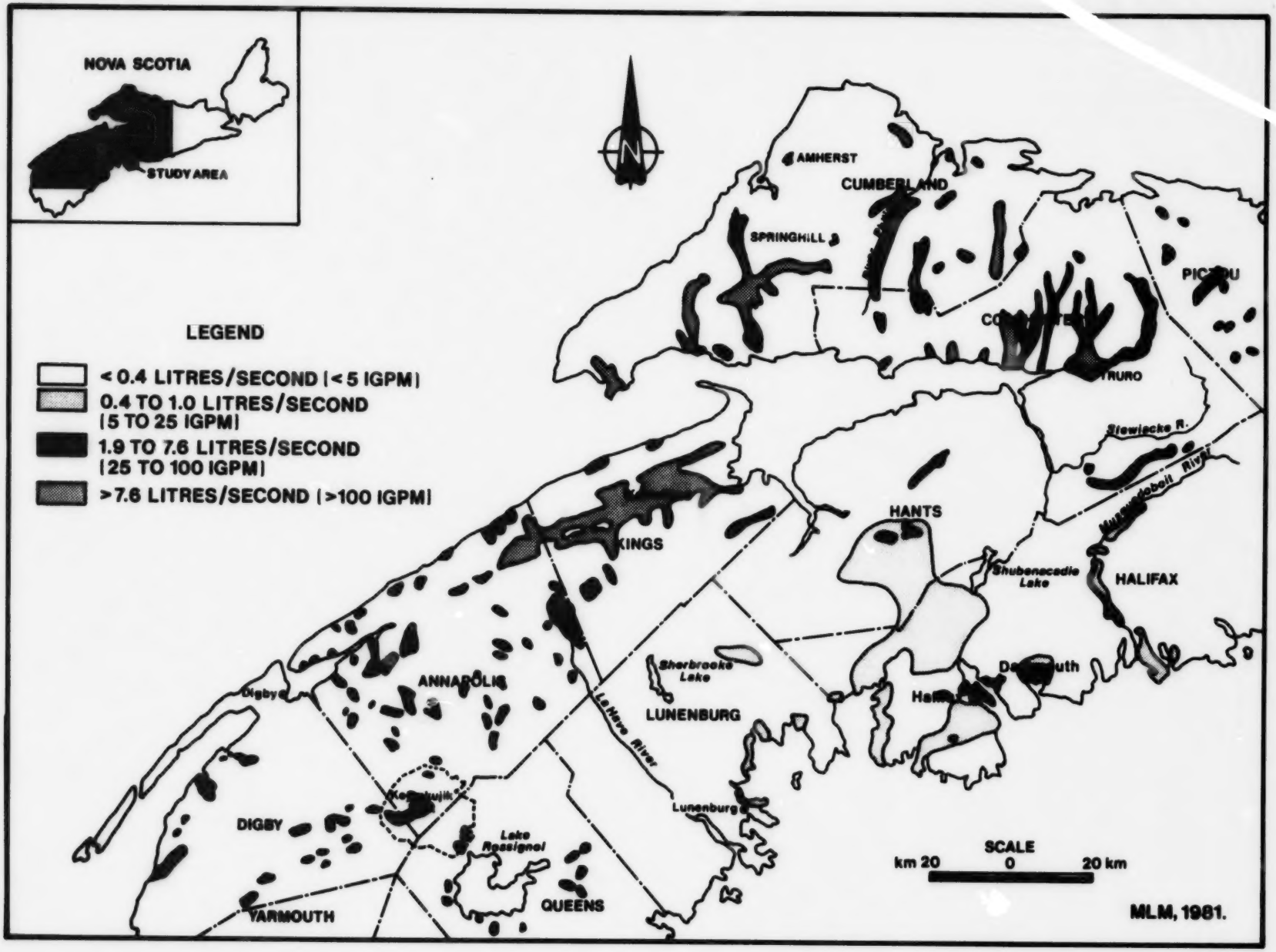

Figure 7. Surficial Aquifers in Agricultural Areas of Nova Scotia

wells is recorded with the Nova Scotia Department of the Environment, although the files could not be located at this time, except for one case.

In Nova Scotia, a number of theses have been done with respect to pesticides and the Nova Scotian environment. The major group of pesticides these studies concentrated on were the organochlorine pesticides. Although heralded initially as almost ideal pest control chemicals, organochlorine pesticides have since become notorious because of their toxicity and their potentially chronic toxic hazard to man and their high persistence. They are in the food we eat and the water we drink.

It has been demonstrated that pesticide residues have entered streams from surrounding agricultural lands in the vicinity of Habitant Creek, mortheast of Centreville, Nova Scotia, by means of leaching and erosion of the surface soil (Burns, G.B., 1973). Residues of various organochlorine pesticides have been found also in the water of the Cornwallis River (Musial, C., 1975). Table 4.13 gives the pesticide concentrations in silts from the Cornwallis River Study. Increase in pesticide concentration in stream water toward stream outlet has been reported in an area near the Cornwallis River watershed (Burns, G.B., 1973). Rivers, therefore, play a particularly important role as a route of entry of these pollutants into the environment.

A study by Paul Michael (1975) on the persistence of 2,4,5-T in Nova Scotian soils has demonstrated leachability of this herbicide with contributions to subsurface flow. Thus the transfer of 2,4,5-T residues, which have been washed through the upper organic horizons, would conceivably continue into groundwater systems. Well water samples were analysed in the Habitant Creek area from a study conducted by G.B. Burns (1973). The wells were located fairly close to the stream beds where the water table was only a few feet below ground level. A well water sample, taken from Woodside, showed detectable quantities of dieldrin and DDT. Background water samples posed a problem, as all surface water tested (streams, reservoirs, holding ponds, etc.), contained measurable quantities of pesticides. Well water was chosen as an alternative, and occasionally showed a slight organochlorine pesticide concentration.

6.0 NEWFOUNDLAND

6.1 Agricultural Production and Major Use Pesticides

There are four crop production areas in Newfoundland (Greenslade, 1985); the northern half of the Avalon Peninsula the Codroy Valley, the Deer Lake-Cormack Area, and the Lethbridge area. The majority of agricultural production occurs in of the northern half of the Avalon Peninsula. Small fruit farming in Newfoundland includes about 99 hectares, mostly strawberries. Five hundred and forty-two hectares are in vegetable production, predominantly turnips, cabbage and carrots. Of the 7,254 hectares in field crops, a majority are tame hay, potatoes, oats and some corn.

Agriculture is not a big industry in Newfoundland, and therefore the total volume of pesticides used is not great. A list of the "major use" agricultural pesticides sold in 1982 in Newfoundland is tabulated in Table 6.

TABLE 5

MAJOR USE AGRICULTURAL PESTICIDES IN NEWFOUNDLAND AS DETERMINED BY 1982 RETAIL SALES VOLUMES (MONENCO, 1984)

Common Name	Quantity of Product Sold (kg or l)	Probable Use
fensulfothion	1196	Soil sterilant, root blight (cabbage)
carbofuran*	6752	Turnips

* Priority One

6.2 Groundwater Resources in Major Agricultural Regions

6.2.1 Northern Avalon Peninsula

Bedrock Aquifers

Precambrian rocks underlie most of the region (Hutchinson, 1953). Hydrostratigraphic units are defined by Fracflow Consultants, within the areas depicted in Figure 9.

Unit A is the Harbour Main Group which consists of Holyrood Granite - volcanics, sedimentary, intrusive and granitic rocks. Mean well yield in these areas is .4 l/sec.

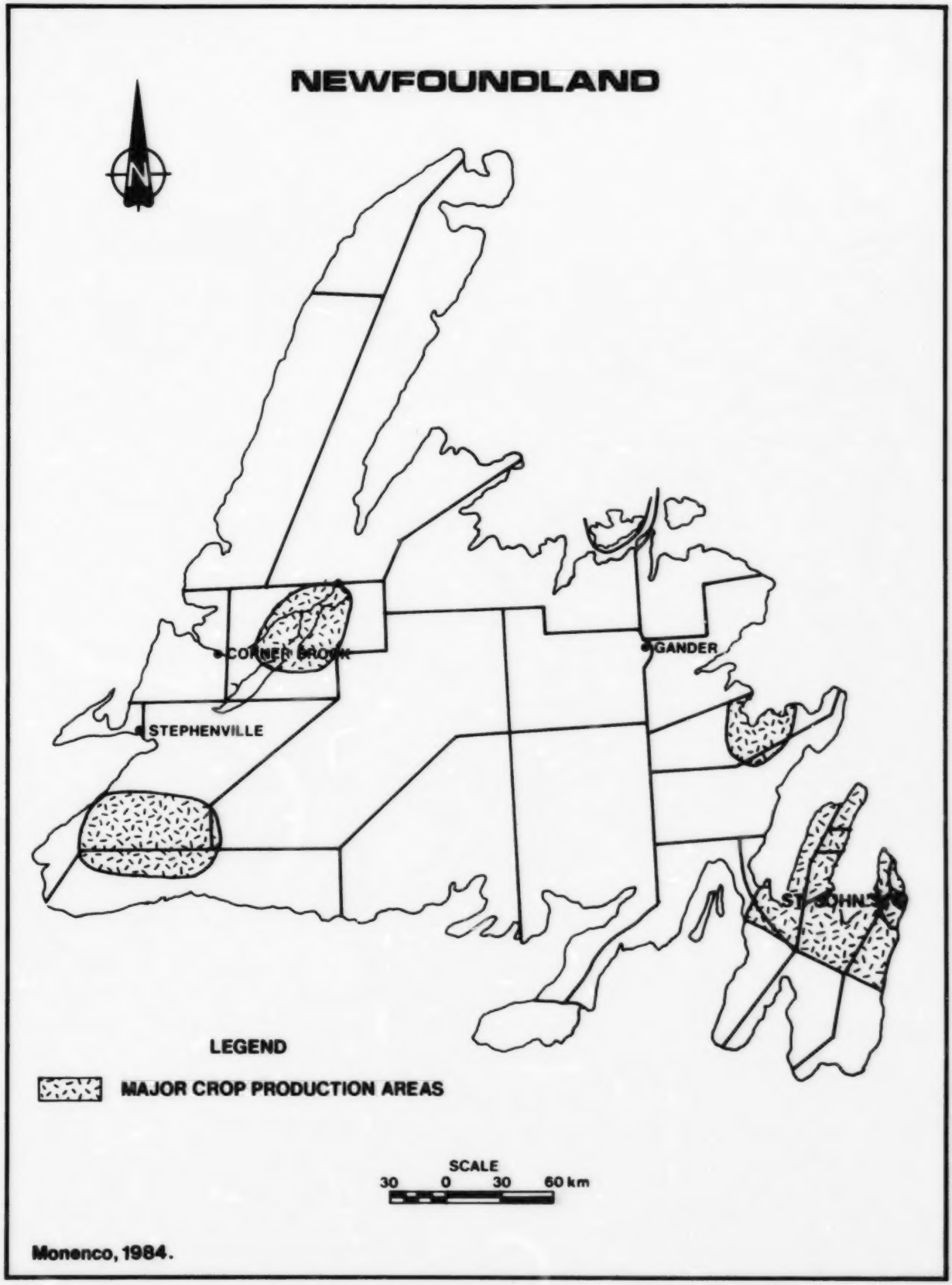

Figure 8. Major Agricultural Areas of Newfoundland and Labrador

Unit B, the Conception and Dildo Groups, which consist of siliceous sandstone, shale, siltstone, tuff, tillate and volcaniclastic conglomerate. Water flow is through fractures only. Yields are lower from these formations - the mean water yield being .3 l/sec (Fracflow, 1984). Units A and B cover the most extensive area in the Northern Avalon Peninsula.

The Signal Hill Group comprises Unit C, and includes breccia, conglomerate, sandstone, siltstone, shale and tuff. A mean yield of .7 l/sec was calculated for these areas (Fracflow, 1984).

Unit D represents the St. John's Group, with shale, slate, limestone quartzite, conglomerate arkose, siltstone and sandstone formations. Water yields from these rocks average .5 l/sec, although occurrences are limited (Fracflow, 1984)

The Wabana and Bell Island Groups, represented by Unit E, are limited to those islands. Sandstone, siltstone and shale make up these higher yielding (1.2 l/sec) bedrock aquifers (Fracflow, 1984).

Drilled wells are becoming more common where institutions or large industries have large water supply requirements (CBCL, 1984)

Surficial Aquifers

Glacial tills are quite porous in the Avalon Peninsula, with numerous sand and gravel lenses throughout. Wells dug in the till yield water sufficient for domestic use; while some settlements such as Clark's Beach can obtain large yields from outwash deposits (Henderson, E.P., 1972). According to Fracflow Consultants, mean water yield from moraine is less than .15 l/sec, while yields from outwash deposits average .7 l/sec. The largest outwash plain extends from Seal Cove to Topsail Head, along the southern coast of Conception Bay. There are also kame deposits scattered throughout the Avalon Peninsula.

Dug wells are more common than drilled wells, but little data are available on these. Water analysis in some cases have shown high iron and manganese levels around Torbay and in the Thorburn Road area (Fracflow, 1984). High nitrate concentrations have been detected in groundwater at Torbay. In some cases, exceptionally high and exceptionally low pH values have been recorded, and it is thought that these are caused by natural processes. Finally, the high chloride and sodium concentrations found in some well water samples may be attributed

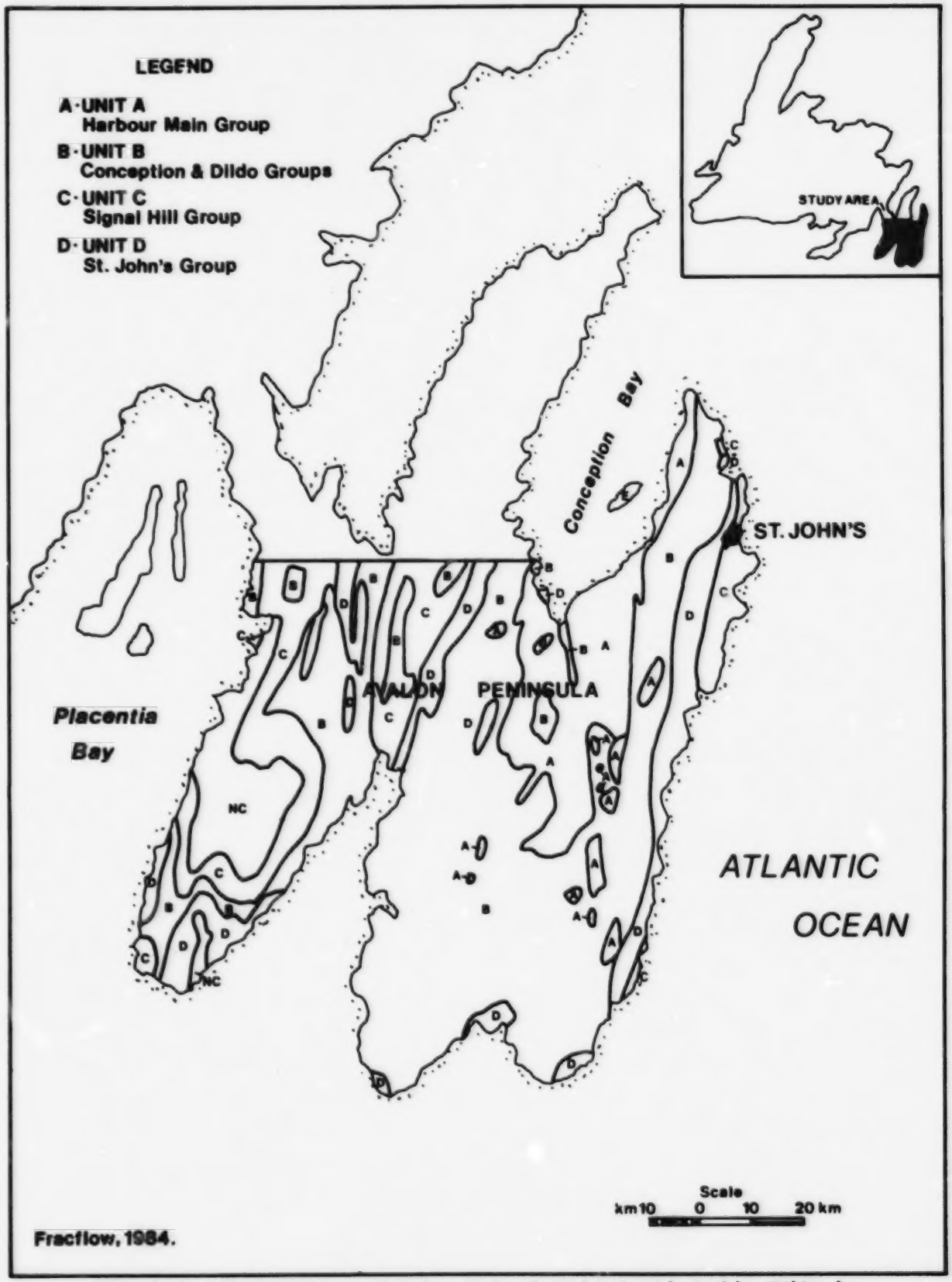

Figure 9. Distribution of Major Bedrock Hydrostratigraphic Units in the Avalon Peninsula

to landfill leachate, road salt, salt-water intrusion, or septic wastes, depending on the location of the well.

Susceptibility of Aquifers to Contamination

Water quality from dug wells in the area indicate that the surficial aquifers are probably susceptible to pollution from land based sources. No monitoring has been done as yet on the newer, usually water soluble agricultural pesticides in current use. Much work needs to be done to assess the possible effects of agricultural pesticides on groundwater quality in Newfoundland.

6.2.3 Contamination Incidents and On-going Research

Very little work has been carried out in Newfoundland with respect to monitoring pesticides in groundwater. The requests for water analysis for pesticides has mainly been directed to forestry spraying, not agricultural practices. Groundwater samples have been analyzed for matacil, DDT and DDE upon request (Hooper, 1985). Preliminary investigation of pesticide occurrences in other provinces of Atlantic Canada reveal that agricultural pesticides occur more frequently in groundwater contamination incidents than forestry pesticides.

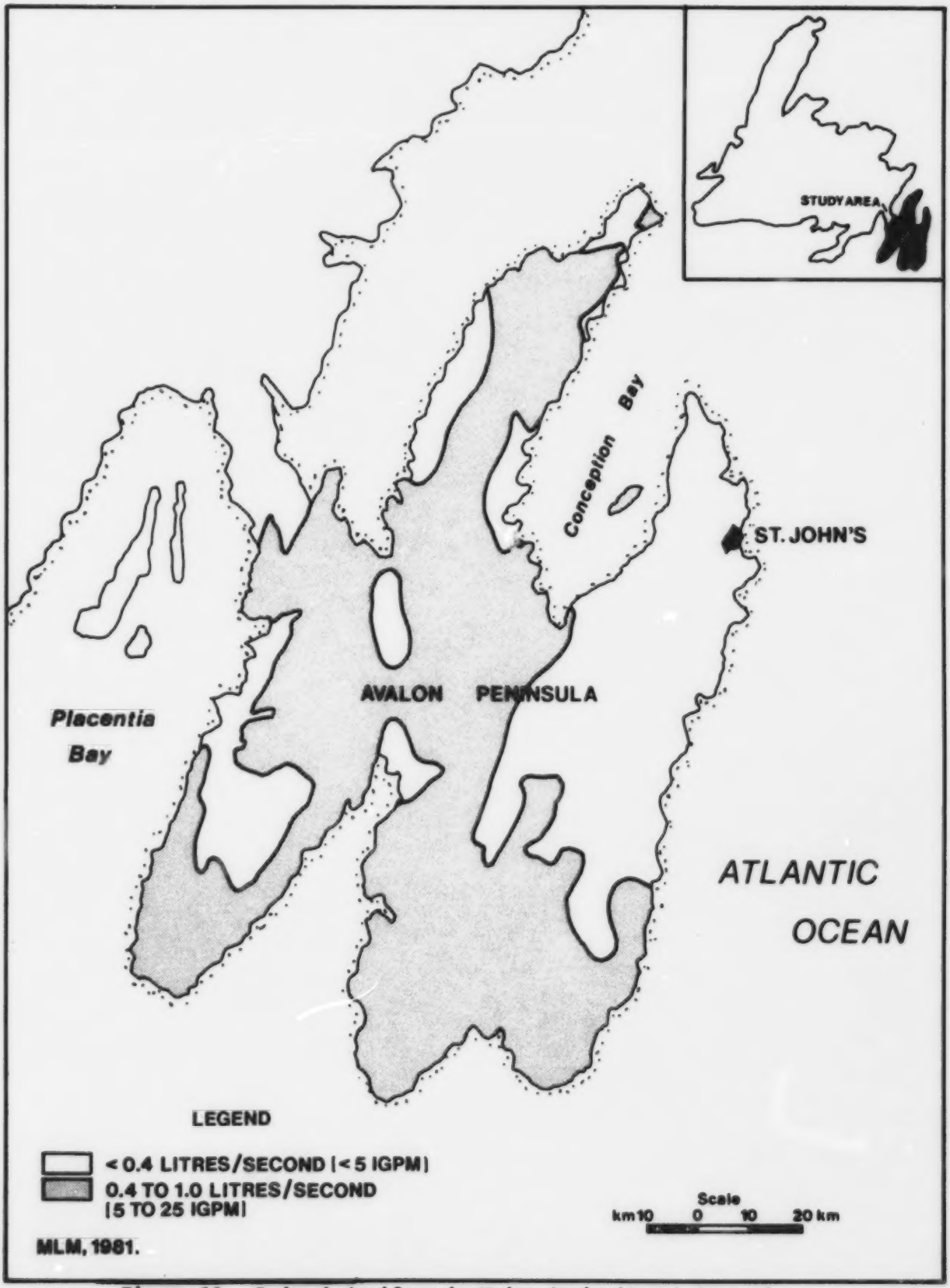

Figure 10. Bedrock Aquifers in Major Agricultural Area of Newfoundland and Labrador

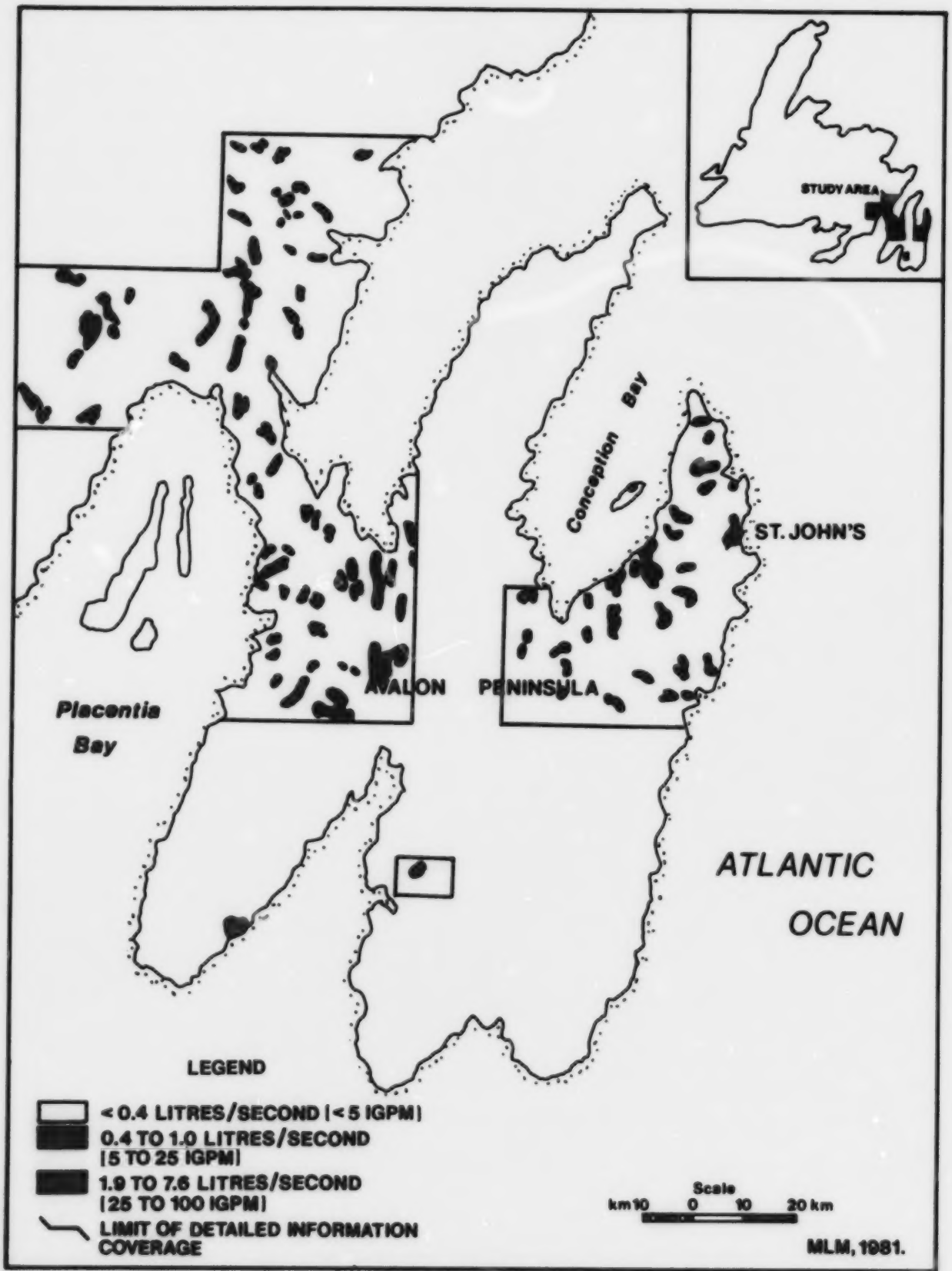

Figure 11. Surficial Aquifers Major Agricultural Area of Newfoundland and Labrador

7.0 Prince Edward Island

7.1 Agricultural Production and Major Use Pesticides

The majority of agricultural production on improved land occurs in Queens County (Personal Communication, Weeks, A., 1985). Small fruit farming in Prince Edward Island includes about 420 hectares, mostly strawberries and blueberries. Approximately 1,718 hectares are in vegetable production, predominantly rutabagas, beets, carrots and cabbage. Of the 106,148 hectares in field crops, most are tame hay, rye, potatoes, mixed grain and oats, with some wheat and tobacco.

A list of the "major use" agricultural pesticides for Prince Edward Island is tabulated in Table 6.

Table 6 suggests that large quantities of herbicides, insecticides and fungicides are commonly used on potatoes and, to a lesser extent tobacco and vegetable crops (EPS, 1984).

7.2 Groundwater Resources of Prince Edward Island

Bedrock Aquifers

The Island is underlain by sandstone, siltstones, mudstones and mudstone breccia. The majority of these rocks are sandstones of alluvial origin. These formations show the typical crossbedding, lensing, discontinuities and rapid facies changes of sedimentary rocks.

There are three major hydrostratigraphic units delineated for Prince Edward Island. The oldest, of Lower Permean Age, is Unit A which is mainly sandstone, with water yields of subzones A_2 and A_3, estimated to be 0.4 - 12.3 l/sec (MLM, 1981). Bedrock Unit B is an agglomerate consisting mainly of coarse grained clastics, containing angular and subangular fragments of gneiss, quartzite, slate, schist, phyllite granite, basalt, grandiorite, and rhyolite. This poorly consolidated friable alluvial fan deposit disintegrates quickly when eroded. Bedrock Unit C is also an alluvial fan deposit which consists primarily of conglomerate and conglomeratic sandstones (MLM, 1981).

Actual well log information is limited, but for the Charlottetown area, yields from the sandstone are estimated to be 0.04 - 6.5 l/sec, based on the calculated transmissivity. In the Summerside area, well yields have been reported as high as 12.3 l/sec. The transmissivity is thought to be dependent on the density and continuity of fractures. It may be generalized that, over the entire island, well yields of 1.6 l/sec can be expected (MLM, 1984).

TABLE 6

MAJOR USE AGRICULTURAL PESTICIDES IN PRINCE EDWARD ISLAND

AS DETERMINED BY 1982 RETAIL SALES VOLUMES (MONENCO, 1984)

Common Name	Quantity of Product Sold (Total kg and/or l)	Probable Use
Insecticides		
aldicarb*	32,706	Potatoes
benomyl**	1,500	Strawberries, potatoes, orchard
carbofuran*	3,220	Mostly potatoes, vegetables, strawberries
disulfoton	50,726	Potatoes
fenvalerate	4,897	Potatoes
methamidophos	1,036	Potatoes
methidathion	4,025	Potatoes
permethrin	1,302	Variety of crops
phorate	32,706	Potatoes
pirimicarb	1,274	Potatoes
ronnel	6,145	Livestock spray
vorlex**	6,319	Soil Fumigant
Herbicides		
atrazine	3,062	Corn
2,4-D	5,795	Grain, strawberries, blueberries
diquat	32,069	Potatoes, vegetables
linuron	1,207	Potatoes, vegetables
MCPA	31,509	Grain
metribuzin	4,561	Potatoes
paraquat	13,201	Potatoes, vegetables
Fungicides		
chlorothalonil	23,333	Potatoes, vegetables
copper sulfate	2,145	Potatoes
mancozeb	85,660	Potatoes, vegetables
metiram	6,640	Potatoes
Growth Regulators		
maleic hydrazide	5,500	Potatoes

* Priority One
** Added by EPS, 1984

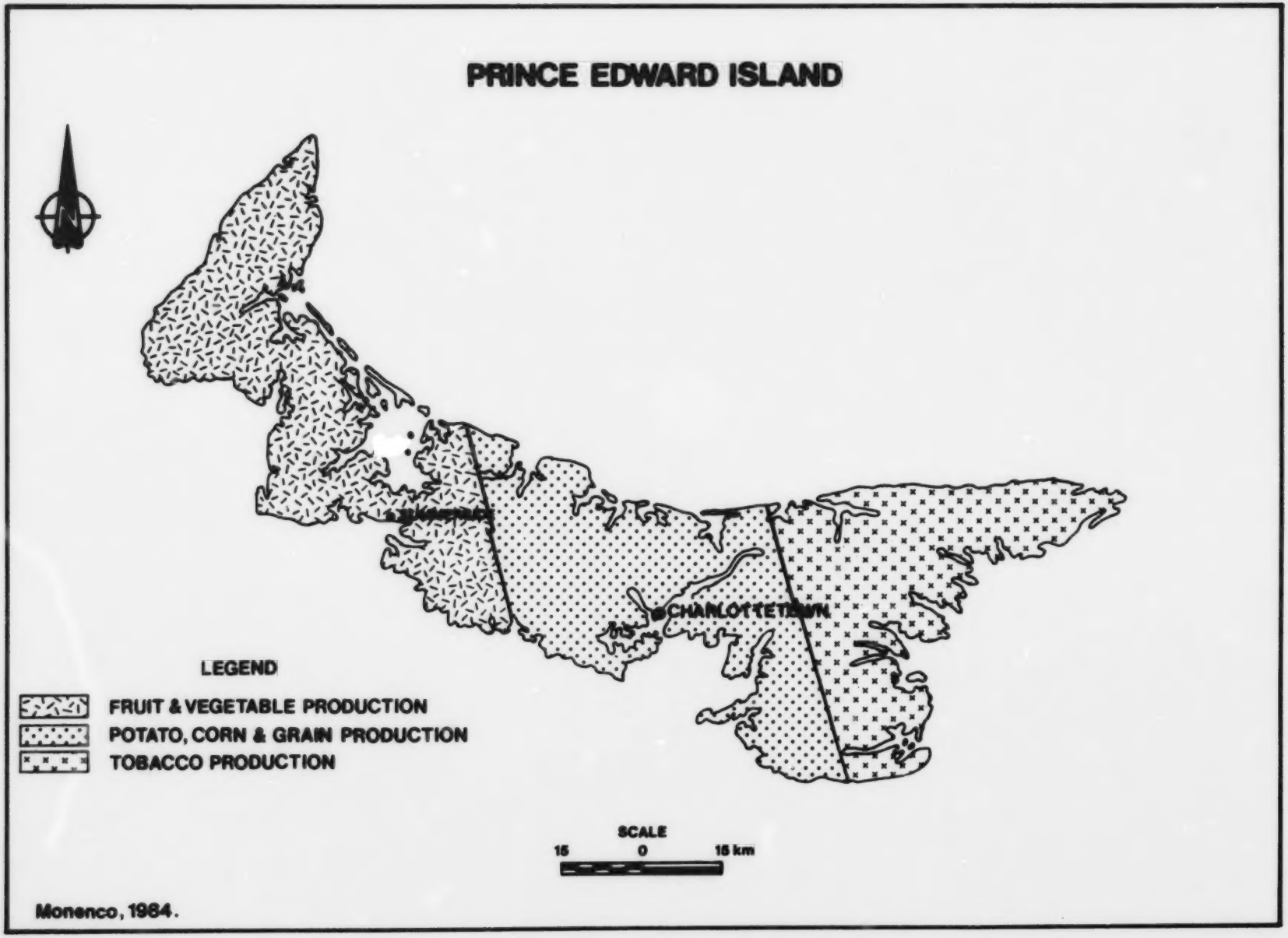

Figure 12. Major Agricultural Areas of Prince Edward Island

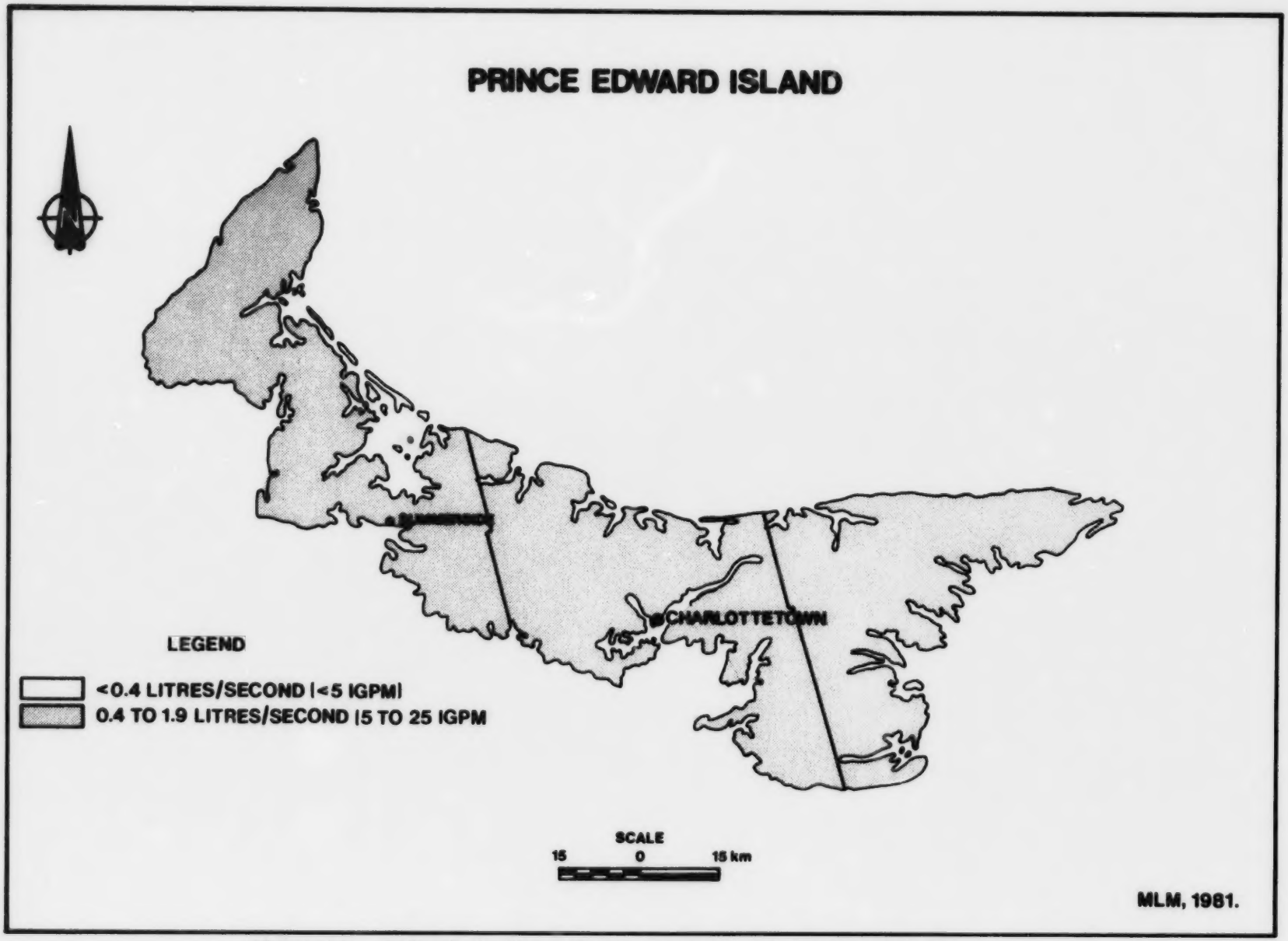

Figure 13. Bedrock Aquifers Major Agricultural Areas of Prince Edward Island

All domestic and industrial water supply uses groundwater as a source. Generally, groundwater quality is good except for pollution problems such as leaking fuel tanks, detection of nitrate levels from agricultural fertilizers, and urea from de-icing operations at the Charlottetown Airport.

Surficial Aquifers

Because Prince Edward Island is covered with only a thin layer of moraine, the surface deposits are not considered as groundwater aquifers (MLM, 1981).

Susceptibility of Aquifers to Contamination

It has been recognized that Prince Edward Island is particularly susceptible to groundwater contamination by pesticides (Jackson, R.E. and H. Liebscher, 1984). Agricultural activity, dependence on groundwater and hydrogeology are contributing factors to this susceptibility. Over 30% of Prince Edward Island's landmass is improved farmland, the highest of any province in Atlantic Canada (P.E.I. Department of Agriculture, 1983).

7.3 Contamination Incidents and On-going Research

In an attempt to determine if any significant amounts of pesticides were present in groundwater, several monitoring programs were inplemented. The Water Resources section of Prince Edward Island's Department of Community and Cultural Affairs, in conjunction with the National Hydrology Research Institute and Evnironmental Protection Service, has been active in monitoring pesticide contamination in surface and groundwaters (Brown J., 1985). They have developed a short list of 19 pesticides which are most hazardous to groundwater in Prince Edward Island. While over 300 pesticides are used in Prince Edward Island (1984 data), only those which have widespread use in the Province, high solubility, considerable persistence and a general probability of being found in groundwater supplies are included (Francis, R., 1985).

The following is a summary of studies conducted by the Water Resources Section, Department of Community and Cultural Affairs. There have also been requests for analyses of well water as a result of spills or from around disposal sites. Information on these are on file with the Water Resources Section, Department of Community and Cultural Affairs, Prince Edward Island (Brown, J., 1985)

Aldicarb Study (1983-84)

For a joint project of the Prince Edward Island Department of Community and Cultural Affairs and the Environmental Protection Service of Environment Canada, water samples from 113 island wells were tested for aldicarb contamination. Sites were chosen throughout the Province in areas of intensive potato production. Sampling sites were selected "on the basis of their proximity to fields where aldicarb was used, and their position in the local groundwater flow system"(Water Resources Branch, 1985). Seven sampling surveys were done over the two year study period in order to evaluate variations in aldicarb concentration during the course of the year.

An internal report from the Water Resources Branch, Investigation of the Insecticide Aldicarb in Ground and Surface Water on Prince Edward Island, covers the first four sample surveys. Results are summarized in Table 7.

Synthetic Pyrethroid, Disulfoton, and Phorate Surveys (1984-85)

A study was carried out by Water Resources Section in cooperation with EPS of Environment Canada as part of a synthetic pyrethroid monitoring program.

Another study on Disyston (disulfoton) and Thimet (phorate) usage on Prince Edward Island was conducted by the Water Resources Section in 1984. Both pesticides are major use pesticides used in potato crops. A sampling program for disulfoton and phorate, two other major use chemicals, besides aldicarb, in potato production. Sites for groundwater testing were chosen beside fields in which the pesticides had been used in recent years. All locations were in the Summerside area.

Results of testing showed one sample positive for disulfoton (0.0002 mg/l) and no positive results for either phorate or the pyrethroids (fenvalerate, permethrin, cypermethrin). See Table 8.

Analyses of surface water, field soil, stream sediment, fish tissue and shellfish were also made for the three synthetic pyrethroids. Only fenvalerate was detected. In soil, concentrations ranged from 16-300 ppb in stream sediment.

These results indicated that at present there is virtually no contamination of groundwater by these pesticides. However, this does not eliminate the possibility of long-term contamination, or contamination by breakdown products.

TABLE 7

SUMMARY OF ALDICARB SURVEY RESULTS

Survey	1	2	3	4	5	6	7
Date	1983 June - July	1983 Sept. - Oct.	1983-84 Dec. - Jan.	1984 Feb.	1984 May	1984 June - July	1984 Aug.
No. of Samples	48	68	59	57	58	57	57
No. (%) Above Detection	13 (27%)	11 (16%)	3 (5%)	6 (11%)	13 (22%)	9 (16%)	9 (16%)
Range	1.0 - 4.6 ppb	1.0 - 5.4 ppb	1.0 - 2.3 ppb	1.0 - 1.9 ppb	1.0 - 4.2 ppb	1.0 - 4.3 ppb	1.0 - 3.6 ppb
Average (Detectable Results)	2.0 - 1.1 ppb	2.2 - 1.4 ppb	2.1 - 0.2 ppb	1.3 - 0.4 ppb	1.7 - 0.9 ppb	1.6 - 1.0 ppb	*1.9 - 1.0 ppb

*Eight values averaged

TABLE 8

SUMMARY OF GROUNDWATER ANALYSES OF DISULFOTON AND PHORATE

Chemical Tested	Result (mg/l)	Location
Disulfoton	<0.0001*	New Annan
Disulfoton	<0.0001	North Bedeque
Disulfoton	0.0002	North Bedeque
Disulfoton	<0.0001	Margate
Phorate	<0.0001	Middleton

*Detection limit for Disulfoton and phorate is 0.0001 mg/l.

Research Study on Pesticides in Groundwater

National Hydrology Research Institute and Prince Edward Island Government hydrogeologists have also studied the migration and fate of aldicarb applied to potato fields at Tryon. Four of the five groundwater samples which had No_3 - N values >10 mg/l also had aldicarb levels of >10 ug/l. Sulfoxide and sulfone were also detected, with the sulfone/ sulfoxide ratio increasing along the groundwater flow path.

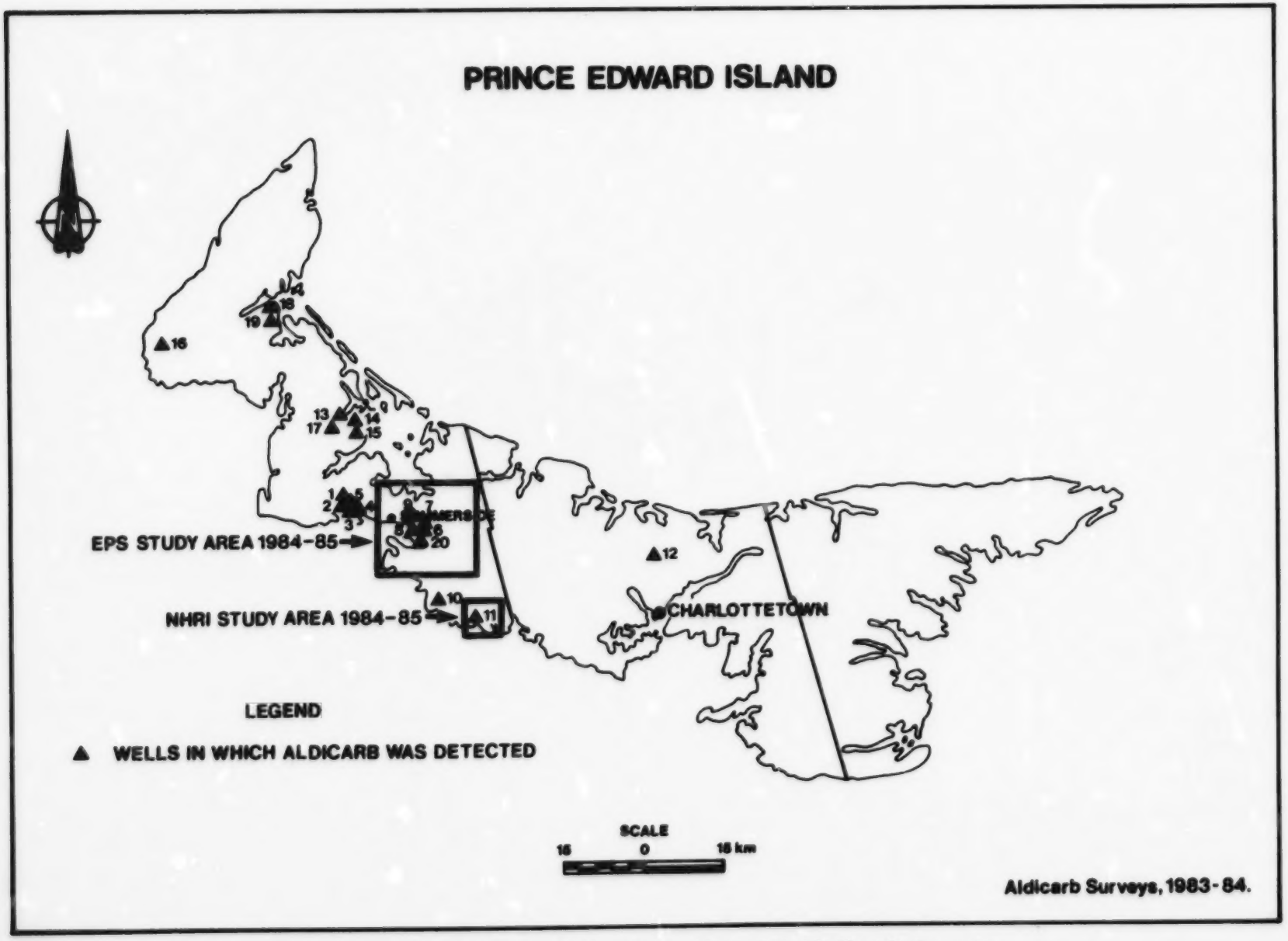

Figure 14. Wells in which Aldicarb was Detected (Aldicarb Surveys, 1983-84), and Other Pesticide Study Areas

8.0 SUMMARY AND CONCLUSIONS

8.1 Summary

The report reviewed the available data and literature sources on the topic of groundwater contamination by pesticides. One objective of this investigation was to provide a collation of available reports on Atlantic Region "major use" pesticides.

A second objective was to develop a list of major use agricultural pesticides which ought to be investigated immediately, on the basis of environmental fate and behaviour, human health effects, and use pattern characteristics. The approach suggested by the National Agricultural Chemicals Association (1985) was adopted, and hence any pesticides detected in groundwater have been grouped into the Priority One list. These are aldicarb, carbofuran, atrazine and dinozeb.

Two important priority listings were obtained from other government agencies; so, if a pesticide appeared on one of these lists, it was designated as a Priority Two pesticide.

Much data was available on the remaining major use pesticides for the region through literature reviews and personal interviews with researchers and governments. An attempt was made to use the available information on the three major criteria noted above in order to develop a further ranking of these pesticides. Hence, a ranking scheme was developed and applied to all the remaining pesticides plus Priority One and Priority Two, primarily as a check of the scheme.

8.2 Conclusions

More agricultural pesticides are used on potato crops in the Atlantic Provinces than any other crop. From the information that is currently available, Carleton County in New Brunswick, Queens County in Prince Edward Island, and Kings County in Nova Scotia are the ultimate destinations of the majority of agricultural pesticides in the Atlantic Region.

In these areas of extensive and intensive agricultural pesticide usage, the susceptibility of surficial and/or bedrock aquifers is very high. Where underlying parent materials are coarsely textured and permeable, adjacent aquifers are prone to contamination by infiltration. In these areas, such as Kings County, Nova Scotia, aquifers tend to be quite extensive, so contamination with pesticides is a very serious matter.

In Newfoundland and Labrador, agriculture is found primarily in four widely separated areas of the province: Codroy Valley, the Deer Lake-Cormack area, the Lethbridge area (Bonavista Peninsula) and the northern half of the Avalon Peninsula. Pesticide use in the Avalon Peninsula is not as extensive or intensive as in the major agricultural areas of the other provinces.

To assist in the protection and management of the groundwater resources of the Atlantic Region, evaluation procedures should be applied to screen and identify those chemicals posing a potential threat to drinking water supplies. The full impact of pesticides on groundwater has yet to occur, if the pesticides and their toxic derivatives are chemically stable within the saturated and unsaturated zones of the soil types in the region.

9.0 RECOMMENDATIONS

1. As pesticide application is greatest on potatoes in Queens County, Prince Edward Island, it may be generalized that Queens County should be an area to concentrate on studies for groundwater contamination by pesticides. Aldicarb is a major use pesticide on potatoes in Prince Edward Island, and its metabolites have been detected in New Brunswick groundwater in areas where this pesticide has been applied. A monitoring site in Queens County should be established to determine if groundwater contamination by this pesticide exists.
2. A major area lacking information is the quantity of pesticides applied in Atlantic Canada. The information used in this report was the best that was available. However, a better system should be developed for the collection of information on pesticide usage in the provinces. It is recommended that a joint Federal/Provincial planning committee be established to co-ordinate the collection of pesticide usage data. Data on pesticide storage, handling and disposal, as well as spills should be included.
3. Further identification and evaluation of aquifers potentially vulnerable to pesticide contamination is required for the major agricultural areas of the Atlantic Region. The data obtained from such surveys are required to identify locations where groundwater contamination by field application (non-point sources) of pesticides are most likely to occur.

4. A joint Provincial/Federal project should be initiated to determine potential impacts on water resources from the application on pesticides, especially areas of agricultural application. Emphasis should be placed on human health effects.

5. For pesticides suspected to be potential groundwater contaminants, field studies should be performed on chemical movement and fate in Atlantic Region soils and groundwater systems. Present studies conducted in other parts of the world do not always represent the Atlantic Region's worst case conditions.

6. Further educational efforts need to be launched in Atlantic Canada for operators applying pesticides. Courses should be developed and made available on a regular basis to assist farmers and other pesticide users in minimizing the risk potential of groundwater contamination. These courses should be designed to familiarize the operators with the relationship between the groundwater resource and the movement of pesticides. The importance of the groundwater resource should be emphasized.

7. Agricultural development in areas surrounding groundwater sources, production wells and groundwater recharge areas should be planned so that the danger of spills of pesticide chemicals, or repeated unintentional applications of pesticides is limited as much as possible. Groundwater supplies in several areas, such as Kensington, Prince Edward Island and Carleton County, New Brunswick, have been contaminated by pesticides through normal use.

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APPENDIX A

TABLE A-1

PRIORITY TWO AGRICULTURAL PESTICIDES FOR THE ATLANTIC REGION

Priority Two- On Federal/Provincial List[1], EPA list of Analytes[2], or in a Problem Group[2]

Common Name	Score	Type	Action	Where Used In Atl. Prov.	Fed/Prov. List (Requestor)	EPA List of Analytes
chlorothalonil	(40)	pthalonitrile	F	NS, NB, PEI	-	II
metiram	(40)	EBD - CBM[3]	F	NS, NB	-	-
zineb	(40)	EBD - CBM[3]	F	NB, PEI	-	-
phorate	(38)	OP	I	NB, NS, PEI	NB, PEI	-
metribuzin	(35	unsymp. triazine	H	NB, PEI	-	II
carbaryl	(33)	CBM	I	NS, NB	-	II
disulfotan	(32)	OP	A I	NS, NB, PEI	-	II
dichlorpropane 1,2 (Vorlex)	(32)	OC	N	PEI	-	I
hexaninone	(31)	triazine[1]	H	NS	-	-
methamidophos	(29)	OP	I,A,P	PEI	-	-
fenvalerate	(28)	SP	I	PEI	NB	-
malathion	(27)	OP	I	NS, NB	NB, DOE	-
methidathion	(27)	OP	I	PEI	PEI	-
dalapon	(27)	chloralkyl acid	H	NB	-	I
pirimicarb	(25)	CBM	I	PEI, NB	PEI	-
azinphos-methyl	(23)	OP	I,A,P	NS, PEI	PEI	-
2,4-D	(23)	phenoxy	H	PEI, NS, NB	-	yes
paraquat	(23)	pyridine	H	NB, PEI, NS	-	yes
maleic hydroxide	(19)	pyridazine	G R	PEI, NS	-	-
linuron	(17)	subst. urea	H	NB, PEI	-	-
chloroxuron	(15)	subst. urea	H	NS	-	-

Key to Pesticide Actions: I - insecticide, H - herbicide; F - fungicide; N - Nematicide; A - acaricide; GR - growth regulator.

Key to Pesticide Types:

- CBM - carbamate
- EBD-CBM - ethylene bis dithiocarbamate
- OP - organophosphate
- OC - organochlorine
- Subst. urea - substituted urea
- SP - synthetic pyrethroid

References

1. Federal/Provincial Working Group, 1985: List of Candidate Chemicals for Revised Drinking Water Guidelines.
2. Cohen, S.Z., 1984b, United States Environmental Protection Agency, Memo to Chairman of ODW/OPP Work Group regarding Criteria for Chemical Selection and Attached List of "Draft Analytes for the National Survey".

TABLE A-2

REMAINING MAJOR USE AGRICULTURAL PESTICIDES FOR THE ATLANTIC REGION
(PRIORITY THREE)

Score	Common Name	Type	Action	Where Used
39	benomyl	CBM	F	NS
37	fensulfothion	OP	I,N	Nfld
36	MCPA	phenoxy	H	PEI, NB, NS
33	diquat	pyridine	H	PEI, NS
32	thiophanate methyl	CBM	F	NB
31	EPTC	CBM	H	NB
30	mancozeb	EBD-CBM	F	NB, NS, PEI
29	captan	pthalamide	F	NS, NB
26	copper sulfate	copper comp.	F	PEI
25	mineral oil	-	I, H	NB, NS
24	glyphosate	aliphatic acid	H	NS
23	thiabendazole	anthelmintic acid	F	NB
20	dichloran	chlorinated nitro-analine	F	NB
20	permethrin	SP	I	P.E.I.
19	dichlone	napthoquinine	F	NS

Key to Pesticide Actions:
I - insecticide, H - herbicide; F - fungicide; N - nematicide;
A - acaricide; GR - growth regulator.

Key to Pesticide Types:
CBM - carbamate
EBD-CBM - ethylene bis dithiocarbamate
OP - organophosphate
OC - organochlorine
Subst. urea - substituted urea
SP - synthetic pyrethroid

References

1. Federal/Provincial Working Group, 1985: List of Candidate Chemicals for Revised Drinking Water Guidelines.

2. Cohen, S.Z., 1984b, United States Environmental Protection Agency, Memo to Chairman of ODW/OPP Work Group regarding Criteria for Chemical Selection and Attached List of "Draft Analytes for the National Survey".

TABLE A-3

PESTICIDE COMPARISON TABLE

Environmental Fate and Human Health Criteria**

COMMON NAME	DETECTED IN GROUNDWATER	WATER SOLUBILITY	SOIL PERSISTENCE (1/2 LIFE)	HUMAN HEALTH EFFECTS	ACUTE ORAL RAT LD_{50} mg/kg body weight	
aldicarb	N.B., PEI, Canada Fla., NY, USA	6000 ppm	[32 days][10 wks](1)	Metabolites suspect	high	.79
atrazine	IA, WI, NB, USA	33. ppm @m25°C	7 months[4-57 wks](1)		low,	3080.
azinphos-methyl		33. ppm	1-3 weeks		high,	11.
benomyl		33. ppm	relatively	Suspect	low,	9590.
captan		<.5 ppm	65 days	Suspected carcinogen	low,	9000.
carbaryl		40. ppm	1-several weeks	Suspected teratogen (2)	mod.,	250.
carbofuran	NY, WI, U.S.A.	700. ppm	[30-60 days]	Suspected carcinogen and teratogen	high,	10.
chlorothalonil		6. ppm @ 25°C	[4-8 wks](1) Metabolites persist	Metabolites more toxic	low,	10000.
chloroxuron		3.7 ppm @ 20°C	60 days		low,	3700.
copper sulphate	-	-	-		mod.,	350.
2,4-D		625. ppm @ 20°C	4-18 weeks		mod.	375.
dalapon		500,000 ppm (1)	> 60 days		low,	6500.
diclone	-	insoluble	-	-	low,	1300.
dichloran	-	-	1 week		low,	> 5000.
dichlorpropane 1,2		.26g/100g			mod	140.
dinoseb	P.E.I. NY, USA	50. ppm	2-8 weeks	Might see reduction products(1) Dinoseb + salts are toxic	mod.,	58.
diquat		70g/100 ml	long persistance		mod.,	230.
disulfoton		25. mg/l	6-8 weeks [8-10 wk] sulfoxide; [42 wk] sulfone(1)	Metabolites suspect	high,	2.6
EPTC		375. @ 20°C			low,	1630.
fensulfothion		1.54g/l	4-9 months		high,	2.
fenvalerate		<1 mg/l	[6 weeks]	Metabolites more toxic	mod.,	451.
glyphosate		350g/l @ 20°C	28-112 days		low,	4320.
hexaninone		33g/kg @ 25°C			low,	1690.

TABLE A-3 (cont'd)

PESTICIDE COMPARISON TABLE**

COMMON NAME	IN GROUNDWATER	WATER SOLUBILITY	SOIL PERSISTENCE (1/2 LIFE)	HUMAN HEALTH EFFECTS	ACUTE ORAL RAT LD_{50}	
linuron			120 days	Not carcinogenic, teratogenic, nor embryotoxic	low,	1500.
malathion		145 ppm	brief-moderate		low,	2800.
maleic hydrazide			short persistence		low,	2340.
mancozeb		paractically insoluble	4-6 weeks	Metabolites teratogenic (4), carcinogenic (ETU)	low,	8000.
MCPA		.08%	3-9 months		low,	700.
methamidophos		9 g/100 ml	1-3 weeks		high,	30.
methidathion		250 ppm @ 20°C	3-5 weeks		high,	25.
metiram		insoluble	[4-6 months]	Metabolites teratogenic (4) (ETU'S)	low,	6200.
metribuzin		1220. ppm (1)	17-60 days [6-36 weeks](1)		low,	2200.
mineral oil					low*	
paraquat		completely soluble	6-23 days	suspected teratogen(4)	mod.,	150.
permethrin		.2 ppm	[6-12 days]	metabolites more toxic		4000
phorate		50 mg/l	6 months		high,	2.
pirmicarb		2.7 g/l	short		mod.,	147.
ronnel	used as livestock fly repellant					
thiabendazole	used as potato storage fungicide				low,	3300.
thiophanate methyl		soluble	long persistence	not mutagenic, cytogenic	low,	7500.
zineb		.001g/100g	[23 days]	Metabolites Teratogen carcinogenic	low,	5200.

* No Rat LD_{50} available, but dose to toxic effect in mouse = 520 mg/kg
LD_{50} dose assumed to be >520 mg/kg.

** See also Use Pattern Comparison - Table A-5.

(1) Cohen, S.Z., 1984a

(2) McEwan and Stephenson, 1979.

TABLE A-4

PESTICIDE COMPARISON TABLE**
Use Pattern Criteria

Pesticide	Type	Crops	Pests	Application Type	Maximum Application Rate kg/ha (active ingredient)	Frequency of Application in one season (or by type)	Timing (in regards to infiltration events)
aldicarb	insecticide nematicide acaricide	potatoes	aphids and other pests	pre-emergent	2.25	(I)	apply before rain
atrazine	herbicide	corn, orchard crops, grain	grasses and broadleaf weeds	pre-emergent and early post-emergent	67.0	(H)	May to early June
azinphos methyl	insecticide acaricide	orchard crops, strawberries blueberries	apple maggot coddling moth	to furrows to crop	.425	1-2x	May or June
benomyl	fungicide	strawberries potatoes, apple crop	mildew, scab etc.	foliar	.6	every 2 weeks, summer through fall	
butylate	herbicide	corn		pre-planting	3.4	(H)	no rain
captan	fungicide	fruit trees strawberries		to crop	4.5	repeat sprays	
carbaryl	insecticide	fruit, vegetables, field crops		to crops	2.2	repeat as necessary	
carbofuran	nematicide insecticide acaricide	potatoes vegetables corn		to furrows	5.5	1X	
chlorothalonil	fungicide	potatoes vegetables	blight	to crops	3.0	(F)	
chloroxuron	herbicide	strawberries vegetables		pre-emergent	5.5	(H)	
copper sulphate	fungicide	potatoes	blight	foliar	2.5	(F)	
2,4-D	herbicide	corn, cereal crops, pasture		post-emergent	.3	(H)	
dalapon	herbicide	potatoes	grass	pre-planting pre-emeregent	8.5	repeat as necessary with low doses	mid summer

TABLE A-4 (cont'd)

PESTICIDE COMPARISON TABLE**
Use Pattern Criteria

Pesticide	Type	Crops	Pests	Application Type	Maximum Application Rate kg/ha (active ingredient)	Frequency of Application in one season (or by type)	Timing (in regards to infiltration events)
dichlone	fungicide	orchard crops strawberries field crops vegetables	scab, blight	to crop	.75 (.25 kg/1000 ml)	repeat at 5-10 day intervals	
dichloran	fungicide	onion, peas	smut	to crop	5.1	(F)	
dichlorpropane, 1, 2	soil fumigant	strawberries		Incorporate into soil	48.0	(SF)	
dinoseb	herbicide	potatoes vegetables		top killer	2.4	2X	
diquat	herbicide	potatoes		top killer	.8	1X	
disulfoton	insecticide	potatoes cereal crops fruit, vegetables		to crop	1.1	(I)	
EPTC	herbicide	potatoes, beans, peas tomatoes		pre-planting incorporate into soil	6.75	(H)	
fensulfothion	insecticide nematicide	soil treatment	root maggots	to soil	2.2	(H)	
fenvalerate	insecticide nematicide	potatoes	diptera, lepidopters	to crop	.33	(I)	
glyphosate	herbicide	croplands	weed control	foliar	4.4	(H)	
hexaninone	herbicide	blueberries	weed control	foliar	4.5	(H)	before rain
linuron	herbicide	potatoes, corn		pre or post emergent	2.2	(H)	
malathion	insecticide	fruit, vegetables, grains		to crop	3.3	repeat as necessary	
maleic hydrazide	growth regulator	potatoes		to crop	3.3	One	

TABLE A-4 (cont'd)

PESTICIDE COMPARISON TABLE**
Use Pattern Criteria

Pesticide	Type	Crops	Pests	Application Type	Maximum Application Rate kg/ha (active ingredient)	Frequency of Application in one season (or by type)	Timing (in regards to infiltration events)
mancozeb	fungicide	potatoes, vegetables, orchard crops	blight, etc.	to crop	2.75	repeat as necessary	
MCPA	herbicide	grain		foliar	4.5	(H)	higher rates in high rainfall areas
methamidophos	insecticide acaricide	potatoes	beetles, aphids	to crop	1.1	repeat as necessary, 7-10 day intervals	
methidathion	insecticide acaricide	food and forage crops		to crop	1.6	(I)	
metiram	fungicide	potatoes apples	blight, mildew, scab	foliar	4.8 (1.6 kg/1000 l)	repeat as necessary, every 7-10 days	
metribuzin	herbicide	potatoes		pre and post emergent	1.1	(H)	
mineral oil	insecticide acaricide	orchard crops	mites, scale	to crop	100 l/ha	2X	
paraquat	herbicide	potatoes, vegetables		post-emergent	.6	(H)	
permethrin	insecticide	general crops		to crop	.2	up to 15 times per season	
phorate	insecticide	potatoes, corn vegetables		to crop, soil	2.2	(I)	
pirimicarb	insecticide	potatoes apples	aphid	to crop	.27	repeat as necessary	
thiabendazole	fungicide	potatoes		for storage protection	N/A	N/A	N/A
thiophanate methyl	fungicide	blueberries strawberries orchard crops	scab, leaf diseases	soil drench, seed piece treatment	.8	up to 6X	

TABLE A-5

OVERALL PESTICIDE SCORING TABLE

Common Name	Type	Maximum Score 20 Soil Leaching Potential		Maximum Score 20 Human Health Effects		Maximum Score 16	TOTAL SCORE
		Water Solubility	Soil Persistance or Half Life	Chronic Effects (mg/kg)	Acute Oral LD_{50} Rat	Use Pattern Characteristics	
aldicarb	CBM	10	10		2	13	45
- metabolites				10 (m)			
atrazine	triazine	10	10	5	2	9	36
azinphos-methyl	OP	10	0	5	0	8	23
benomyl	CBM	10	10	10	0	9	39
captan	pthalonitrile	0	0	10	0	11	21
carbaryl	CBM	10	0	10	1	12	33
carbofuran	CBM	10	10	10	2	11	43
chlorothalonil	pthalonitrile	10	10		0	10	40
- metabolites				10 (m)			
chloroxuron	subst. urea	0	0	5	0	10	15
copper sulphate	copper compound	5	5	5	1	10	26
2,4-D	phenoxy	10	0	5	1	7	23
dalapon	chloralkyl acid	10	0	5	0	12	27
dichlone	napthoquinine	0	5	5	0	19	26
dichloran	chlorinated nitro-analine	5	0	5	0	10	20
dichlorpropane 1,2	OC	10	5	5	1	11	32
dinoseb	dinitrophenol	10	0		1	11	32
- metabolites				10 (m)			
diquat	pyridine	10	10	5	1	7	33
disulfoton	OP	0	10		2	10	32
-metabolites				10 (m)			

* See Table A-7 for Use Pattern Scoring

(m) = metabolites are the problem

TABLE A-5

OVERALL PESTICIDE SCORING TABLE

Common Name	Type	Maximum Score 20 Soil Leaching Potential: Water Solubility	Soil Persistance or Half Life	Maximum Score 20 Human Health Effects: Chronic Effects (mg/kg)	Acute Oral Rat LD_{50}	Maximum Score 16 Use Pattern Characteristics	TOTAL SCORE
EPTC	CBM	10	5	5	0	11	31
fensulfothion	OP	10	10	5	2	10	37
fenvalerate	SP	0	10		1	7	28
- metabolites				10 (m)			
glyphosate	aliphatic acid	10	0	5	0	9	24
hexaninone	triazine	10	5	5	0	11	31
linuron	sube urea	5	0	2	0	10	17
malathion	OP	10	0	5	0	12	27
maleic hydrazide	pyridazine	5	0	5	0	9	19
mancozeb	EBD-CBM	0	0		0	12	30
- metabolites				18 (m)			
MCPA	phenoxy	10	10	5	0	11	36
methamidophos	OP	10	0	5	2	12	29
methidathion	OP	10	0	5	2	10	27
metiram	EBD-CBM	0	10		0	12	40
- metabolites				18 (m)			
metribuzin	triazine	10	10	5	0	10	35
mineral oil		5	5	5	0	10	25
paraquat	pyridine	10	0	5	1	7	23
permithrin	SP	0	0		0	10	20
- metabolites				10 (m)			
phorate		10	10	5	2	11	38
pirmicarb	CBM	10	0	5	1	9	25
thiabendazole*	enthelmintic acid - potato storage fungicide						
thiophanate methyl	CBM	10	10	2	0	10	32
zineb		0	10		0	12	40
- metabolites				18 (m)			

* Potato storage fungicide, not rated

TABLE A-5 (cont'd)

PESTICIDE COMPARISON TABLE**
Use Pattern Criteria

Pesticide	Type	Crops	Pests	Application Type	Maximum Application Rate kg/ha (active ingredient)	Frequency of Application in one season (or by type)	Timing (in regards to infiltration events)
zineb	fungicide	potatoes orchard crops	seed treatment, pinpoint scab	to crop	22.0	repeat as necessary	

Information was obtained mainly from the following references:

1. Agriculture Canada, 1985.
2. Guide to the Chemicals Used in Crop Protection, Agriculture Canada, 7th Ed.
3. Landreville, Linda, 1985.
4. Lewis, Grace, 1985.
5. Monenco, 1984
6. Parisienne, Roche, 1985.
7. Thomson, 1974a and b
8. Sittig, M, 1980a.
9. Seatech Investigative Services Ltd., 1982
10. Worthing, C., 1983.

** See also Table A-4, Pesticide Comparison Table - Environmental Fate and Human Health Criteria

TABLE A-6

PESTICIDE SCORING TABLE
Use Pattern Criteria

Pesticide	Application Type	Application Rate	Frequency In One Season (or by Type)	Timing In Regards to Infiltration Events	Total
aldicarb	3	4	2	4	13
atrazine	3	4	1	1	9
azinphos methyl	3	1	2	2	8
benomyl	2	1	4	2	9
captan	1	4	4	2	11
carbaryl	2	4	4	2	12
carbofuran	3	4	2	2	11
chlorothalonil	2	4	2	2	10
chloroxuron	3	4	1	2	10
copper sulphate	2	4	2	2	10
2,4-D	3	1	1	2	7
dalapon	3	4	1	4	12
dichlone	2	1	4	2	9
dichloran	2	4	2	2	10
dichlorpropane 1,2	4	4	1	2	11
dinoseb	3	4	2	2	11
diquat	3	1	1	2	7
disulfotan	2	4	2	2	10
EPTC	4	4	1	2	11
fensulfothion	3	4	1	2	10
fenvalerate	2	1	2	2	7
glyphosate	2	4	1	2	9
hexaninone	2	4	1	4	11
linuron	3	4	1	2	10
malathion	2	4	4	2	12
maleic hydrazide	2	4	1	2	9
mancozeb	2	4	4	2	12
MCPA	2	4	1	4	11
methamidophos	2	4	4	2	12
methidathion	2	4	2	2	10
metiram	2	4	4	2	12
metribuzin	3	4	1	2	10
mineral oil	2	4	2	2	10
paraquat	3	1	1	2	7
permethrin	3	1	4	2	10
phorate	3	4	2	2	11
pirimicarb	2	1	4	2	9
thiabendazole	potato storage fungicide				
thiophanate methyl	3	1	4	2	10
zineb	2	4	4	2	12